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XLV

THE VENOUS NETWORKS OF THE NASAL MUCOSA

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Recording the variations in the size and arrangements of blood vessels has occurred since the beginning of anatomy. Curiously, in these lists, be they in English, French, German or Japanese, there is no mention of the variations of the vessels nor the architectural patterns within the nose. This is true for both the arteries and the veins. The reasons for this lack are easy to find. Formerly, the nose was treated as an organ like the spleen or kidney. Variations are listed for the anterior facial vein or the internal maxillary artery, but only for their extra-nasal course. The last seventy-five years, the life span of the American Laryngological Association, has seen the birth and development of rhinology as a specialty. As late as

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1880, there were arguments as to whether the head mirror was a useful instrument. Opponents contended that the mirror should be fixed to the light rather than to the head, and the observer and patient oriented accordingly. The detailed study of the nose began in 1882 with Zuckerkandl's[1] well-illustrated *Anatomy of the Nasal Cavity*. The small size of the nasal vessels makes them difficult to dissect. Further, the general dissecting room has little time to spend on parts concerned with a medical specialty. Zuckerkandl's descriptions of the nasal blood vessels were augmented by accounts of serious bleeding in clinical practice. Among the early reports was the one of Little,[2] who described bleeding from the lower anterior part of the septum. A few years later, Kiesselbach[3] went over the same ground. The terms "Little's area" and "Kiesselbach's area" denote a region of the septum prone to bleed. We have assumed the bleeding to be due to a peculiar arrangement of blood vessels located here. Some of us have used one eponym for venous bleeding and the other eponym for an arterial flow. Close survey of papers of Little and Kiesselbach does not justify this differentiation. Kiesselbach was indefinite while three of Little's four cases were definitely arterial bleeding. Neither author described the anatomy of the vessels. Perhaps we should use the eponyms to describe the area without any presumptions as to the vascular pattern. Recently Professor Swindle,[4-6] making use of his extensive familiarity with comparative forms, gained through association with zoological collections, has given detailed accounts of the nasal arteries and veins and their finer connections. He reported the arrangement in the reindeer and the kangaroo since he considered these forms to represent types. He described interrelations of vessels rather than their gross distribution. Harper[7] in 1947 gave a preliminary report of his studies of the venous network in the human nose. In his summary he indicated that the arterial supply had a course in the periostial layer or in the bone itself and that the finer ramifications of the arteries broke up into the rich venous network of the substantia propria of the nasal tissues.

Detailed study of the finer ramifications of the vascular system cannot be made by dissection. Injection methods are necessary to see the small vessels. After the injection has been made, there are several ways of handling the material. One of the methods is that of corrosion. This consists in using an injection mass which becomes solid and then, by one of the several means, destroying all of the surrounding tissues and retaining only a cast of the interior of the

Fig. 1.—Corrosion specimen. Human, adult.. Left lateral nasal wall. A, anterior; P, rich plexus of veins in the eustachian tube area; S, sphenoid sinus with lining of veins. Note, that while only veins are shown, the lateral wall anatomy appears normal, except for the artifacts produced in sawing the specimen.

vessels. The method began with Schwammerdan in 1672. A somewhat parallel method, probably just as old although its age is difficult to determine, uses a dried specimen. Here the vessel is filled with a mass, and the soft parts allowed to lose substance in cold running water for two or three weeks, after which the parts are dried. The filled vessels now stand up sharply against the shriveled remains of the soft tissues. Most of our older book illustrations of vessels were made from specimens prepared by this method. A modern method is generally attributed to Spalteholz,[8] who in 1911 placed on a firm scientific basis the making of so-called transparent preparations. The Spalteholz technique was used by Swindle. Recently I have had the good fortune to have available for corrosion specimens a plastic mass which obviates most, if not all, of the drawbacks of the earlier masses. I owe this to the cooperation of Dr. Ernest Rose and the High Polymer Research Laboratory of H. D. Justi and Son, Inc., dental manufacturers in Philadelphia. This mass

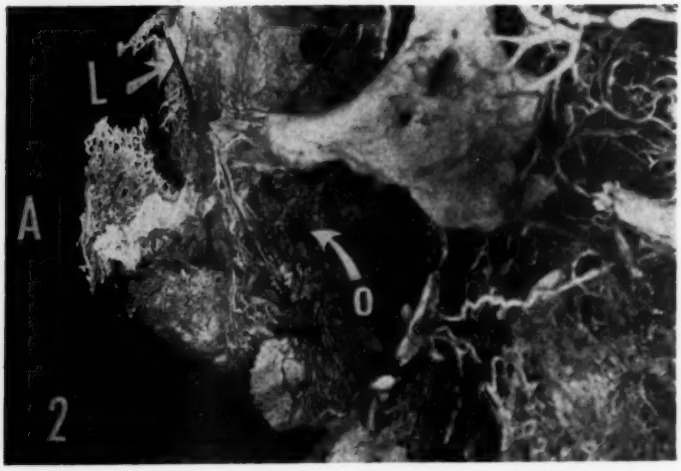

Fig. 2.—Corrosion specimen. Human, adult. Same specimen as Figure 1, but seen from without. A, anterior; L, probe in the cylindrical venous plexus surrounding the nasolacrimal apparatus; O, ostium of the maxillary sinus from within the sinus. The continuity of the nasal veins and the sinus veins is obvious.

is a methyl-methacrylate which can be made to polymerize at room temperature. The shrinkage is not more than 15 per cent. Intimate relations of the blood vessels to one another, over large areas, are more readily seen than in transparent preparations. The transparent preparations which I have made earlier are better understood by a study of the corrosions.

The following description of the veins of the human nose is based upon a series of corrosion preparations made with the new methacrylate mass mentioned above. These corrosions give an overall view of the veins of the nasal mucosa, the paranasal sinuses, the nasal vestibule, and the nasal skin. They show the location of the principal draining veins and suggest several clinically significant relationships.

The specimens here reported are adult and new-born human material. The method chosen for injecting the veins may seem un-

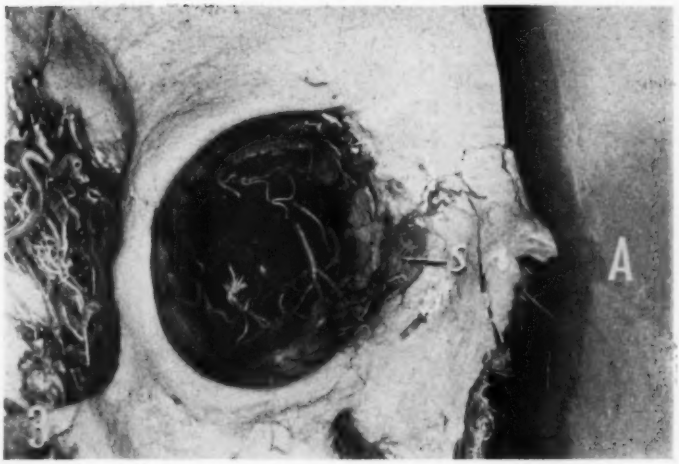

Fig. 3.—Corrosion specimen. Human, adult. Dorsum of the nose and right orbit. A, anterior; S, plexus of the saccus lacrymalis.

orthodox. When it is recalled that with minor exceptions there are no valves in the veins in the head and neck, the logic of the method will be apparent. In one specimen, a deep brachial vein was isolated and the injecting cannula was directed toward the trunk. By this method, the fluid methacrylate solution entered the trunk veins to flow into the deeper neck veins. From these neck veins, the solution passed upward to the head and eventually to the veins of the nasal mucosa. In other specimens, the external jugular veins was the site of injection, the cannula being directed toward the head. In still others, one or both internal jugular veins were used. In every instance, the mass was fluid enough to find numerous escape outlets so that undue pressure was not developed. In using new-born material, it is necessary to ligate enough arteries so that a reflux cannot occur back to the head on the arterial side by way of the open foramen ovale and the patent ductus arteriosis. The vascular system was not profused before injection since in my experience it is not necessary. Although I am completely familiar with the pulsed pressure method of injection and use it on occasion, I did not feel that

Fig. 4.—Corrosion specimen. Human, adult. The nasal septum seen from the left side. A, anterior; V, the coarser plexus over the vomer. Other points noted in the text are readily made out.

it was necessary in these specimens. All of our material was at least one week post-mortem, and all had been preserved by refrigeration.

The low viscosity and the easy flowing characteristics of this mass made the direct injection of the turbinates, as practiced by Zuckerkandl, unnecessary.

A corrosion specimen of the veins of the lateral nasal wall is startling in that it appears that the soft tissues are fully represented by the network of the cast (Fig. 1). It is as if the surface covering had been removed and everything else remained. Looking at such a specimen, it seems difficult to find place for the arteries and glands known to be present in the turbinates. This is due in part to the fact that with continuous pressure, most of the venous channels have been opened, and the corrosion preparation actually gives us the appearance of the veins when engorged, as in an inflamed state. By actual measurement, the mat of veins is from 1 mm to 4 or 5 mm in thickness, depending upon the area. The thickness is greatest in the rhinopharynx and on the turbinates. The veins themselves range

from a diameter of 0.1 mm to 1.0 mm or slightly larger. The veins are rarely more than a millimeter from each other, usually much closer. There are many interconnections. In the olfactory area the principal venous stems have a vertical course reflecting the course of the olfactory nerve filaments (Fig. 1). Over the rest of the lateral wall, they have the same general sweep as the nasal conchae themselves; that is, they slope obliquely downward and backward. At the ostia of the sphenoidal and maxillary sinuses, the network continues through into the cavities of the sinuses themselves. Here the veins are of the smaller ranges of diameter averaging less than 0.5 mm. It is to be remembered that these dimensions are for the internal diameters since these are casts. The mat of veins is about 0.5 mm in thickness. Although the normal sinus mucosa is pale and almost transparent, these specimens show that there is a rich venous plexus. Obviously it is capable of extemporaneous distention. As stated above, this injection represents something of the order of a maximum filling. Whether the sudden clinical thickening of the sinus membranes is due to engorgement with blood or to edema, a rich vascular network is necessary for either change to occur.

In specimens where the lateral bony nasal wall has disintegrated during maceration, the course of the naso-lacrimal duct can be followed upward by following the peri-lacrimal network of veins (Figs. 2 and 3). This network forms a definite cylindrical mesh which follows upward and encompasses the saccus lacrimalus. In these specimens, it looks as if the saccus were in place. Actually, all we see is the cast of the interior of the veins of the peri-saccus plexus. From this peri-saccus plexus, one or more veins run directly to the anterior facial vein.

This extensive communication of the peri-saccus veins with the veins of the nasal mucosa seems to offer an explanation for the swollen saccus area seen in young children during an acute coryza. The clinical picture looks like an acute dacryocystitis except that an acute inflammation here, as a primary entity, is practically unknown. Further, with adequate shrinkage of the nasal mucosa, the swelling of the saccus area subsides in a few hours. It would be difficult to say whether the swelling was due to the venous engorgement of the peri-saccus veins or whether the engorgement of these veins produced an obstruction to the duct itself. The latter explanation may be the proper one since such swelling is not encountered in adults, where the size of the duct is much larger. This plexus of the lacrimal

Fig. 5.—Corrosion specimen, human, neo-natus. P, indicates the venous plexus within the nasal cavity, and on the left side of the specimen the plexus of the skin of the nasal tip has been preserved. A, covers an alar vein and S, covers a saccus vein.

apparatus has been known for a long time, but it is rarely described and seldom illustrated.

The valveless continuity of the sinus venous network with that of the nasal cavity could account for the presence of fluid in the sinuses during an acute coryza without an actual infectious invasion of the sinus cavity. The early venous engorgement responsible for the increased nasal secretion unquestionably produces a sinus secretion.

As the venous mat of the nasal cavity nears the vestibule, the surface vessels seem as rich, but there are fewer layers. Here the net-

work of the mucous membrane continues with the subcutanous vestibular network of veins, and these in turn with the subcutaneous nasal veins over the alar cartilages. From this subcutaneous plexus, veins which could be called inferior alar veins, connect with the anterior facial vein.

The continuity of the submucosal and the subcutaneous network of veins over the alar cartilages furnishes the anatomic basis for the red and swollen nasal tip characteristic of the early stages of an acute infection (Fig. 3). The skin is in the same injected state as the mucous membranes in the nose. Parenthetically, the acute tenderness of this skin is due to its close attachment to the perichondrium. This is similar to the outer surface of the ear. Over the upper cartilage and the bone, the skin has a loose subcutaneous tissue, and the venous plexus is not so rich.

It is scarcely necessary to point out the rich venous plexus of the rhinopharynx which folds around the orifice of the eustachian tube (Fig. 1). The swelling of this orifice is so well-known that emphasis is unnecessary.

The nasal septum bears a network of veins similar to the lateral wall. Here the network is only 0.5 mm to 0.1 mm in thickness. The veins run parallel to the course of the olfactory filaments in the upper part of the nose and run in an irregular, horizontal course in the lower portion. They seem to parallel the course of the ethmo-vomer suture. In our specimens, the venous network covering the vomer is composed of larger and more widely separated veins than the network covering the perpendicular plate of the ethmoid. This is true in our small series and may be a universal finding. I feel that this should be studied further before expressing a final opinion.

It will be seen (Fig. 4) that in addition to the usually named veins of drainage, there is a whole series of veins from the nose which join the anterior facial vein beginning at the level of the saccus lacrimalus and proceeding downward. Some of these veins now grouped as external nasal veins might properly be given special names because of their clinical significance, e.g., the vein of the lacrimal sac and the alar veins.

It might be asked whether the venous pattern shown to exist in the nose is characteristic of the veins of the other mucous membranes when demonstrated by this method. To take the immediately

adjacent tissues of the mouth as a good example, it can be categorically stated that the venous network is neither as rich nor as thick as it is in the nose.

SUMMARY

The mucous membrane of the nasal cavity is pervaded throughout by an interlacing venous network consisting of vessels of from 0.1 mm to 0.5 mm and even larger in internal diameter. These veins are a valveless network. They communicate everywhere with each other and with the veins of the underlying bone. The thickness of the venous network parallels the thickness of the mucous membrane itself. It must be recognized that even within the sinuses with their thin mucosa, there is a rich venous network in a more or less collapsed state.

Photographs by Mr. Alex Vaskelis.

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XLVI

CONGENITAL ANOMALIES OF THE LARYNX

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Congenital anomalies of the larynx are of interest to the embryologist and clinician. This subject is reviewed and the various types of anomalies seen in the past ten years analyzed according to the symptoms they present, the laryngoscopic picture and the therapy which was instituted.

The congenital anomalies of the larynx will be discussed under the following headings: 1) congenital laryngeal stridor; 2) congenital webs; 3) congenital atresia; 4) congenital subglottic stenosis; and 5) congenital cysts and laryngoceles.

An understanding of the embryology of the larynx is necessary for an appreciation of the development of its anomalies. The larynx undergoes differentiation between the fourth and tenth weeks, and noxious agents affecting the developing embryo at this time may cause malformations of this structure, just as they may adversely affect other organs developing during the same period. The upper portion of the larynx arises from the pharyngeal floor in the region of the primitive glottis. That part from the vocal folds caudally forms around the stem of the trachea.[1] The epiglottis develops as a rounded prominence that elevates midventrally from the bases of the third and fourth arches. This soon alters its shape and consolidates into a transverse flap. It becomes concave on its laryngeal surface and in the middle of fetal life differentiates cartilage internally. The slit that opens from the floor of the pharynx into the trachea is

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the primitive glottis. It is bounded on each side by a rounded eminence, the arytenoid swelling of fourth and fifth arch origin. These two swellings begin to grow in a tongueward direction and on meeting the primordium of the epiglottis they arch upward and forward against its caudal surface. In the seventh week this results in the original, sagittal slit adding a transverse groove to its upper end, so that the laryngeal orifice becomes T-shaped. However, the entrance to the larynx ends blindly for some time because fusion of the epithelium in the upper larynx has obliterated the lumen. When the epithelial union is dissolved (ten weeks) the entrance becomes more oval in contour and a pair of lateral recesses is evident in the restored cavity. These recesses are the laryngeal ventricles. Each is bounded cranially and caudally by projecting lateral shelves, the caudal pair are the vocal folds which later differentiate elastic tissue.

The epithelial larynx is supported by dense mesenchyme derived from the fourth and fifth branchial arches. Early in the seventh week this mass shows localized condensations that foretell the laryngeal cartilages. The laryngeal muscles also originate from the same branchial arches and consequently continue to be innervated by the vagus nerves which supply those arches.

CONGENITAL LARYNGEAL STRIDOR

So-called congenital laryngeal stridor is a transient form of stridor in infants which is associated with a softness or abnormal flaccidity of the laryngeal tissues. For this reason, it is occasionally referred to as "laryngomalacia" or "congenital flaccid larynx." However, as Kelemen[2] has indicated, stridor can be produced almost anywhere in the larynx by bulky parts or protruding folds; thus, stridor is a symptom which is generally associated with respiratory obstruction rather than with a specific disease entity, and consequently the term is somewhat ambiguous. Therefore, in every infant with stridorous, noisy respirations, a differentiation must be made as to whether the symptoms are produced by the soft, flaccid structures of the larynx, the clinical entity of congenital laryngeal stridor, or by some organic obstruction due to other congenital anomalies, or a lesion acquired in infancy.

During the past seven years, 305 infants with congenital laryngeal stridor have been seen. Of these 199 were males and 106 females. Only one of these required tracheotomy. Typically, the stridor is present from birth and is usually audible only on inspiration. It may

be constant or intermittent and may vary with the position of the infant, being louder when the infant is on its back and quieter or absent when the infant is on its abdomen. The fluttering nature of the stridor may lead one to suspect that the infant's hypopharynx is filled with mucus, and that aspiration will relieve the condition. Synchronous with the stridor may be fluttering intercostal, suprasternal or epigastric retractions.

A number of infants with congenital laryngeal stridor were noted to have funnel breast (pectus excavatum). The association with micrognathia, as suggested by Schwartz[3] was by no means apparent in this group of patients. Many of the stridorous infants had been irradiated for an ostensibly enlarged thymus gland. Littleton et al[4] discuss the fallacy of this too common diagnosis. Of course, if the gradual relief of congenital laryngeal stridor coincidentally follows thymic irradiation, it is then incorrectly concluded that the thymus was to blame.

Laryngoscopy is necessary to establish the diagnosis definitely and to rule out other causes of stridor. In the majority of cases, the epiglottis was the structure from which the fluttering sound originated, although the arytenoids were frequently involved with the epiglottis. Typically, the epiglottis is curled and may be tube-shaped in extreme instances.[2] The reason for this curling is not entirely understood, but it may be explained by a review of the development of the epiglottis which originates from the bases of the third and fourth arches. It is possible that the anterior half, or third arch contribution, has a propensity for more rapid growth than has the posterior half, or fourth arch contribution. This difference in the rates of growth of the two halves of the epiglottis would explain the curling of the structure in the infant, and the extreme curling in infants with congenital stridor. As the curled epiglottis is drawn into the laryngeal aperture with each inspiration, the typical stridor is produced (Fig. 1 A and B). Arytenoids which are long and flaccid flutter with each inspiration (Fig. 1 D), and they, too, are drawn into the laryngeal lumen along with a flaccid, curled epiglottis.

The one case of congenital laryngeal stridor which required tracheotomy was an extreme example of this condition. The infant had stridor from birth, and laryngoscopic examination when he was six weeks old showed the typical laryngeal flaccidity which characterizes congenital laryngeal stridor. The epiglottis was soft and

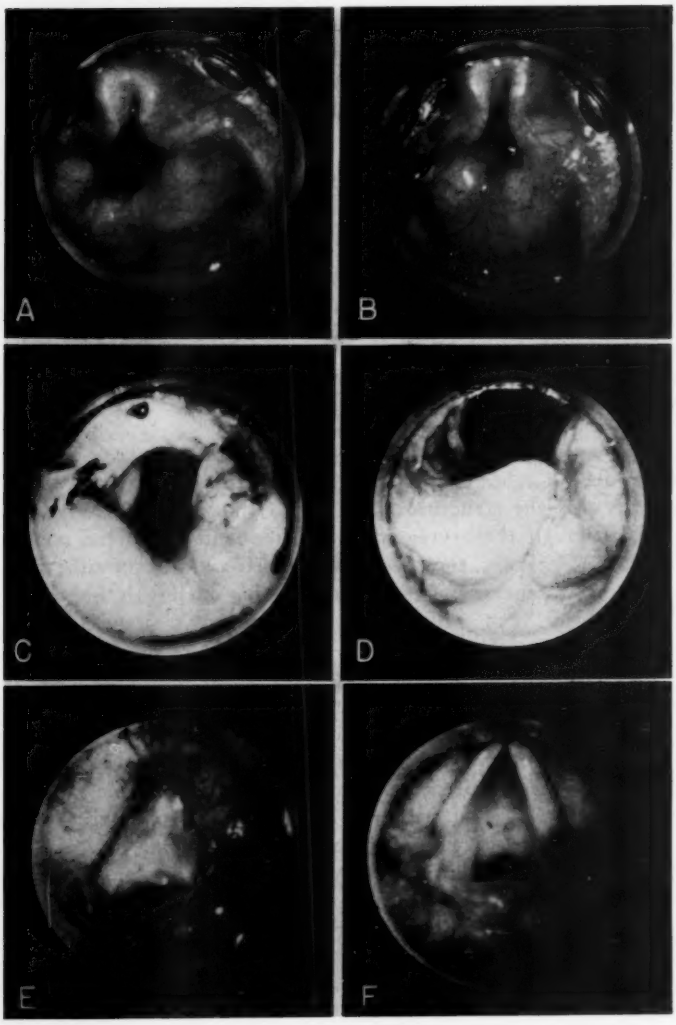
A
B
C
D
E
F

Fig. 1.—Direct laryngoscopic photographs of the larynx showing congenital laryngeal anomalies.

A and B.—Expiration and inspiration, respectively of an infant three months of age with congenital stridor.

C.—Congenital supraglottic web between the aryepiglottic folds at the level of the false cords.

D.—Flaccid, elongated soft parts of the left arytenoid in an adult being drawn into the larynx during inspiration. The right arytenoid followed over the left as inspiration progressed.

E.—Congenital fusion of the anterior half of the cords simulating a laryngeal web.

F.—Symmetrical subglottic stenosis at the level of the cricoid cartilage.

(Figures 1 E and F and Figures 4 and 6 are enlargements of frames of 16 mm motion picture films.)

curled and the lose aryepiglottic folds and flabby arytenoid prominences were drawn into the laryngeal aperture on inspiration, alternately one above the other in a fluttering type of motion. When the tip of the laryngoscope was passed into the vallecula and the laryngeal structures brought under tension through lifting the base of the tongue, the stridor was appreciably reduced. Advancing the laryngoscope under the epiglottis and to its tuberculum resulted in a complete disappearance of the stridor as the tension was increased and the aryepiglottic folds were retracted laterally by the lip of the laryngoscope. Bronchoscopic examination of the trachea showed no evidence of subglottic or tracheal obstruction but all symptoms returned as the laryngoscope was withdrawn. No therapy seemed indicated or necessary in view of the patent airway and the absence of other organic obstruction of the airway. At the age of five months, the stridor and respiratory difficulty had increased; and in addition, because of the respiratory distress, the infant could not feed properly and had hardly gained more than a pound over his birth weight. There had been three attacks of cyanosis accompanied by convulsions. On the evening of readmission to the hospital for study, his laryngeal difficulty became so pronounced that a tracheotomy was indicated and was performed with a bronchoscope inserted to provide the infant with an adequate airway. Repeat studies of the larynx, esophagus and tracheobronchial tree showed nothing more than the flaccid larynx to account for the stridor. Since his tracheotomy, the child is eating and developing normally. There have been no further episodes of cyanosis or convulsions.

The recognition that the typical laryngoscopic picture of congenital laryngeal stridor is present does not rule out other causes of noisy respiration. This is illustrated by the following case:

L. L., male infant three months of age, was first examined on June 7, 1946 because of crowing respirations since birth. Laryngoscopy revealed a curled epiglottis and flaccid arytenoids typical of congenital laryngeal stridor and this diagnosis was considered confirmed by the laryngoscopic picture. However, his stridor persisted and he was re-examined on October 23, 1950 at the age of four years at which time a definite expiratory wheeze was present. Barium studies of the esophagus revealed an oblique, faint indentation crossing the esophagus at the level of the aortic arch in the antero-posterior view, and in the lateral view there was a marked posterior indentation. The trachea was seen to be considerably narrowed and pushed anteriorly at the level of the identation. Laryngoscopy and bronchoscopy at this time revealed a normal larynx, but the posterior wall of the trachea was compressed above the bifurcation. Undoubtedly the fluoroscopic studies of the esophagus at the time of the first examination, which are now done routinely in infants with stridor, would have revealed the aortic arch deformity; but the

laryngoscopic evidence of the typical picture of congenital laryngeal stridor made it appear that further studies were unnecessary in view of the positive findings. The diagnosis of a vascular ring was substantiated at surgery by Dr. Willis J. Potts. A similar case was reported by Wissler.[5]

Finlay[6] reported the clinical course and post mortem findings of three children in one family, all showing congenital stridor. Two of the children died shortly after laryngoscopy, which was performed under general anesthesia. The last case, which was not laryngoscoped, suffered episodes of choking during feedings, and was hoarse. Slight inspiratory retractions were present. Barium swallows showed notching of the posterior wall of the esophagus. Recurrent attacks of pneumonia caused the child's death and post mortem examination revealed an anomalous right subclavian artery and a small larynx. A fourth sibling was normal in all respects.

A complete study of infants with stridor should include a history of the nature of the birth and the time of onset of the stridor, a careful physical examination, especially noticing the character of the cry and its timing and observing whether the fluttering inspiratory sounds are synchronous with fluttering thoracic movements. X-ray studies should include frontal and lateral x-rays of the neck and chest and fluoroscopic studies of the esophagus. Finally, the endoscopic examination is made, confirming or denying the presence of the typical picture of congenital stridor as described above. All types of lesions which may obstruct the airway must be considered. The absence of x-ray evidence of an organic obstructing lesion does not establish the diagnosis of congenital laryngeal stridor by elimination. Only the direct laryngoscopic view can confirm this diagnosis, and rule out such other lesions as laryngeal paralysis or webs which would give no characteristic x-ray findings in infants.

As the infant with congenital laryngeal stridor grows, the larynx becomes larger and more firm, and the abnormal folds gradually uncurl. The stridor frequently disappears between the twelfth and eighteenth months. It is extremely rare that any active therapy is indicated and removal of the bulky parts seems not only unnecessary but dangerous.

CONGENITAL WEBS

Nineteen patients with congenital laryngeal webs have been observed (Table 1). There were nine males and ten females. In thirteen cases the web consisted of a membrane across the anterior por-

TABLE 1.
SUMMARY OF FINDINGS IN PATIENTS WITH CONGENITAL LARYNGEAL WEBS

NO.	PT.	AGE	SEX	SYMPTOMS	POSITION OF WEB	CHARACTER OF WEB	TREATMENT
1	T. T.	5 yr.	M	Hoarseness	Glottis	Membrane	Dilatation multiple
2	L. J.	1½ yr.	M	Hoarse cry	Glottis	Membrane	Dilatation multiple
3	P. R.	1 mo.	M	Dyspnea; absent cry	Glottis	Transparent membrane	Dilatation single
4	L. B.	6 wk.	F	Severe dyspnea; weak, absent cry	Glottis	Fusion of cords	Tracheotomy dilatations
5	E. G.	11 da.	F	Hoarse cry; dyspnea	Glottis	Membrane	2 dilatations
6	M. S.	3 mo.	F	Weak cry; mild dyspnea	Glottis	Fusion of cords	Repeated dilatation
7	W. L.	2 wk.	M	Dyspnea, cyanosis, absent cry	Glottis	Dense membrane, small posterior opening	Tracheotomy incision and dilatation of web
8	B. F.	1 da.	F	Dyspnea, cyanosis, absent cry	Supraglottic	Supraglottic membrane	Incision and dilatation, tracheotomy—died
9	M. F.	31 yr.	F	Hoarseness	Glottis	Small anterior commissure web	Dilatation
10	R. P.	25 da.	F	Hoarseness	Supraglottic	Fusion of false cords	Dilatation

11	B. S.	6 yr.	M	Dyspnea and hoarseness; assoc. with patent ductus	Glottis	Membrane	None
12	J. F.	12 yr.	F	Hoarseness	Glottis	Membrane	Dilatation
13	A. H.	7 yr.	F	Hoarseness	Glottis	Membrane	Incision, dilata.
14	N. B.	17 yr.	M	Hoarseness	Glottis	Membrane	Incision, dilata.
15	R. T.	15 mo.	M	Hoarseness, dyspnea	Supraglottic	Supraglottic, fibrous membrane level of false cords, almost cartilaginous in character; membranous web across anterior half of true cord.	Dilatation
16	F. B.	2 yr.	F	Hoarseness, dyspnea	Glottis	Membrane	Dilatation; this child later developed papilloma
17	G. M.	8 mo.	M	Weak cry, hoarseness and dyspnea	Glottis	Membrane	None (mental deficiency)
18	W. L.	10 da.	M	Cry without sound, dyspnea and cyanosis	Glottis	Membrane	Forceps and bougie dilatation
19	L. B.	3 yr.	M	Squeaky, high pitched cry, hoarseness	Glottis	Membrane across anterior two-thirds of larynx	Dilatation with laryngeal bougies

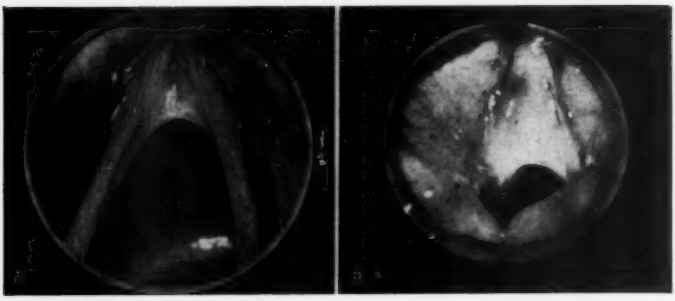

Fig. 2.—Typical congenital membranous webs of the larynx. A. Web across the anterior commissure of a 31- year old female who had been hoarse since birth. B. Web involving the anterior two-thirds of the larynx of a seven year old girl referred from her school because of speech difficulty. A history of hoarseness and dyspnea since birth was obtained.

tion of the glottis at the level of the superior surfaces of the cords, through which the outlines of the phonating edges of the cords could be distinguished. The degree to which the glottis was covered varied from small anterior commissure webbing (Fig. 2 A) to almost complete closure of the glottis (Fig. 2 B). In the majority of cases the anterior two-thirds of the glottis was involved, the tough membrane originating along the entire cord with the exception of the vocal process of the arytenoids; it arched anteriorly to give a posterior chink for respiration.

In one infant an extremely thin, transparent web extended across the anterior one-half of the larynx at the level of the superior surface of the true cords. This infant, a new-born, made no sound on crying and a direct laryngoscopy was performed for diagnostic purposes. The membrane was visualized, split with laryngeal alligator forceps and its edges immediately retracted into the laryngeal mucosa. The infant cried audibly at once and on subsequent examination the larynx appeared entirely normal.

In two infants, the congenital glottic web assumed a configuration which differed from that described above; it appeared to be a fusion of the anterior half of the cords rather than a membranous sheet (Fig. 1 E). In these two infants the anterior half of the

phonating edges of the cords appeared to be in contact with each other, the cords separating posteriorly as an inverted "V." The passage of dilators through the larynx demonstrated a fibrous character to this anterior commissure fusion which extended subglottically and was not similar to the webs described above.

The congenital webs in three patients were supraglottic, an apparent fusion of the anterior half of the false cords; the true cords below were normal in configuration and motility. The appearance of this condition in one patient is shown in Fig. 1 C. The description of the second supraglottic web is incorporated in the following case report:

B. F. was delivered normally at term on September 12, 1951. She was admitted to the hospital at the age of six hours because of marked inspiratory stridor, thoracic retractions and a high-pitched, weak cry. X-rays of the chest and neck showed no abnormality. Direct examination of the larynx was made with an infant laryngoscope and a most unusual picture was immediately observed. The base of the tongue was normal and the epiglottis was extremely small and was drawn posteriorly. The mucosa covering the posterior surface of the cricoid cartilage was visible as the base of the tongue was raised, this mucosa extending anteriorly as a more or less rounded, membranous surface. A tiny, pin-point opening through which respirations were taking place was seen in the midline in the center of this rounded mass. A 3 mm x 20 cm infant bronchoscope was inserted through this opening, dilating it and improving the airway; the true cords and glottic aperture could be visualized below it and appeared to be essentially normal. As the bronchoscope passed through the opening and beyond the cords into the trachea, the respirations became quiet and without effort. The bronchoscope was withdrawn and the larynx reinvestigated by lifting the tip of the epiglottis with the laryngoscope. A membrane appeared to cover the larynx, extending across the laryngeal aperture at the level of the aryepiglottic folds and the false cords. The anterior portion of this membrane was exceedingly thin and transparent, but the posterior aspect was fibrous and thickened and drew the superior surfaces of the arytenoids and the posterior portion of the aryepiglottic folds together over the glottis. A laryngeal knife was inserted into the posterior opening through which the bronchoscope had passed and the web was incised, releasing the tension which held the arytenoids and aryepiglottic folds together. The lumen of the larynx was then visible and the true cords were found to be essentially normal in their appearance and their motility. Following the procedure the patient's respirations were quiet and unobstructed. Consequently, the tracheotomy which had been contemplated was postponed, at least temporarily, to determine whether there had been sufficient improvement in the airway to make the tracheotomy unnecessary. Five days following the original laryngoscopy, the procedure was repeated and the membrane was redilated with laryngeal forceps. After another five day period, the larynx was dilated with a No. 12 laryngeal bougie, but fifteen days later laryngoscopy revealed considerable stenosis of the anterior half of the larynx and it became obvious that dilatation was not entirely satisfactory in keeping the airway open. Consequently, a tracheotomy was performed over a 3 mm bronchoscope and dilatations were then carried out weekly.

On December 2, 1951, the baby took fluids poorly, became irritable, and began expelling excessive blood-tinged mucus from the tracheal cannula. Coarse

rhonchi were present over both lungs and x-rays showed diffuse pneumonitis bilaterally. Acute respiratory distress increased in spite of aspiration and antibiotic management and the next day the child developed convulsions and became cyanotic. She expired on the following day.

Post mortem examination revealed pneumonia involving the right middle, right lower and left upper and left lower lobes. Little evidence of the supraglottic web remained. The epiglottis was abnormally mobile close to its base and was bent posteriorly to lie over the glottis. In its anteroposterior diameter, the glottic chink measured six millimeters. The mucosa over the cords, arytenoids, and epiglottis was edematous, and the mucosa over the cords suggested slight denudation. Sections of the epiglottis and cords revealed the mucosa to be thinned in focal areas. A rich infiltrate of small round cells was present in the submucosa and the blood vessels were dilated and engorged with red cells.

The trachea and bronchi contained a bloody, frothy, viscous material. Except for the tracheostomy, the rings appeared normal and the trachea was not remarkable. Microscopic sections revealed no changes, except for edema of the mucosa and a few inflammatory cells in the submucosa.

Thus, of the nineteen congenital laryngeal webs, twelve consisted of moderately thick membranes across the anterior one-fourth to two-thirds of the membranous portions of the cords; one was a thin, transparent sheet across the superior surfaces of the cords; two were a fusion of the anterior half of the cords without an apparent membrane of any kind between the cords; and three were supraglottic webs which consisted of a membrane connecting the false cords and aryepiglottic folds but not involving the true cords below. The nineteenth patient was an adult who had been hoarse since birth who had a small membrane (Fig. 2 A) across the anterior one-fourth of the larynx. Serology and chest x-rays were negative and she had had no laryngeal inquiry or surgery of any kind. The history and appearance suggests a congenital laryngeal web, but, obviously, absolute proof other than the clinical picture is lacking.

Symptoms of laryngeal webs are present at birth or shortly thereafter and usually consist of a hoarse or weak cry, or a complete absence of sound with crying efforts. Respiratory distress is the second symptom, the degree depending upon the percentage of the glottis which is covered by the web. Three of the thirteen patients with membranous glottic webs were children of school age, referred because of speech difficulties.

The correct diagnosis can only be made by a direct laryngoscopic view of the larynx, but it is imperative that preparations for a possible tracheotomy be completed before the examination is undertaken. This measure is necessary whenever an endoscopic pro-

cedure is being performed in the face of repiratory obstruction; not that the endoscopy will precipitate the tracheotomy, but because of the nature of the pathology which may be found.

Therapy in these patients has been conservative. Two of the infants with membranous glottic webs and one with a supraglottic web have required tracheotomy. In the remaining patients direct laryngoscopic dilatations have been employed. Dilatation of the larynx, occasionally associated with use of the Knight[7] combination scalpel and dilator have proven effective and the more extensive extra-laryngeal surgical procedures have not been necessary. One death from an extensive bronchopneumonia occurred in a tracheotomized infant who had a supraglottic web.

Congenital stenosis, webs, and atresia of the larynx are best explained embryologically by the fusion theory of laryngeal development. Hudson[8] reports that nine cases of congenital webs of the larynx were seen at Babies' Hospital between 1932 and 1949. The hospital admits approximately 4,000 patients yearly. He presents one case of a web extending between the ventricular bands leaving a very small posterior airway. In his discussion of this subject, Clerf[9] presents three cases of laryngeal webs. Two of the webs reported were between the ventricular folds. Clerf explains congenital laryngeal stenosis by the embryological fusion theory. As mentioned in the review of the embryology of the larynx, the developing vocal cords are adherent to each other during the seventh week. After about two weeks, this epithelial fusion dissolves and the opening into the larynx is reestablished. Failure of adequate dissolution may result in development of webs, bands, or complete atresia. McHugh and Loch[10] found reports of 133 congenital webs in the literature and presented an additional case of their own. The majority of the webs (75 per cent) were at the level of the true cords. Supraglottic webs accounted for 1.5 per cent of their series, and 3.7 per cent extended posteriorly. An extensive bibliography of 169 items accompanies this excellent study.

CONGENITAL ATRESIA

Congenital atresia of the larynx is obviously incompatible with life unless the condition is recognized at once at birth and immediate steps are taken to establish an airway. One such case is reported by Jackson and Jackson.[11] Direct laryngoscopic examination of a "blue baby" that had ceased to make respiratory movements immediately

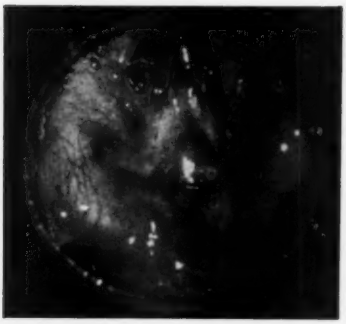

Fig. 3.—Congenital atresia of the larynx of an infant ten months of age. A tracheotomy had been performed at birth when it was realized that while the infant was making strong respiratory efforts, there was no air exchange.

after delivery revealed a complete membranous occlusion of the glottis. A 3 mm bronchoscope was pushed through the web into the trachea and oxygen and artificial respiration administered. The infant responded and after an hour was breathing on his own and the bronchoscope was withdrawn. At six years of age, examination showed thickened cords.

A similar, dramatic instance is herein reported:

D. C. was normally delivered after a full term gestation. The obstetrician noted strong respiratory efforts, with no evidence of air exchange. Thinking quickly, he rapidly performed a tracheotomy with the instruments at hand, establishing an adequate airway before damage from anoxia could take place. This infant was examined at Children's Memorial Hospital on September 13, 1950 when it was ten months old. On lifting the epiglottis, no aperture could be visualized. The epiglottis, hypopharynx, false cords, and arytenoids were seen to be normal. The true cords, however, were joined by a sheet of white fibrous tissue through which their outlines could be distinguished (Fig. 3). No actual lumen was visible, although a pinpoint dimple in the posterior commissure suggested an opening; however, there was nothing to suggest that air passed through on inspiration or cough. The atretic area felt extremely firm, possibly cartilagenous in character, and even with considerable effort it would not permit the passage of the tip of a No. 12 bougie. Efforts to establish a lumen by puncture from above and by retrograde procedures have not been successful. After further growth has taken place other attempts will be made to open through the obstructing membrane. McNaught's[12] method of placing a thin plate of tantalum in the midsaggital plane of the larynx through a slot in the thyroid cartilage, after dividing the membrane, may be effective here. It should be noted that this infant has other congenital anomalies such as hyperelastica cutis (Ehlers-Danlos Syndrome).

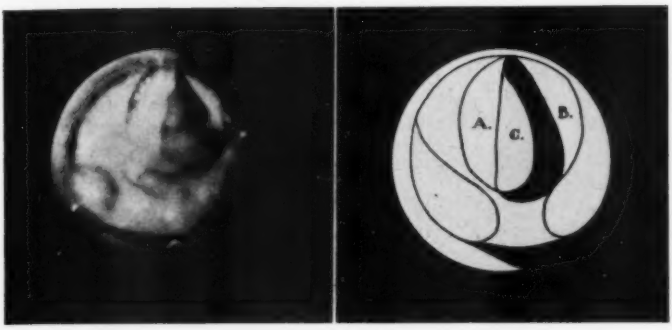

Fig. 4.—Direct laryngoscopic view of subglottic stenosis. The photograph was taken from a 16 mm motion picture frame and the structures are identified in the line drawing on the right. A. Left cord. B. Right cord. C. The left subglottic swelling as viewed through the glottis from the right. A similar swelling under the right cord caused the subglottic stenosis.

CONGENITAL SUBGLOTTIC STENOSIS

This clinical picture is a difficult one to evaluate (Figs. 1 F and 4). It consists of a thickening of subglottic structures and sometimes of the true cords themselves which causes respiratory obstruction of a severe degree in new born infants. The least laryngeal inflammation precipitates a tracheotomy since the limiting cricoid cartilage does not permit swelling of tissues in any direction other than inwardly, at the expense of the airway. The point of greatest obstruction is generally 2-3 mm below the level of the superior surface of the true cords. Biopsy of one such area showed no inflammatory reaction. In two cases, a severe obstructing deformity of the cricoid cartilage was found at necropsy, suggesting that moderate cartilaginous deformities may play an important role in other infants in this category.

Thirty-four cases of congenital subglottic stenosis of the larynx have been seen during the past seven year period. There were twenty males and fourteen females. The earlist symptom of this condition beginning at birth was stridor with or without episodes of cyanosis depending upon the severity of the stenosis. In mild cases, recur-

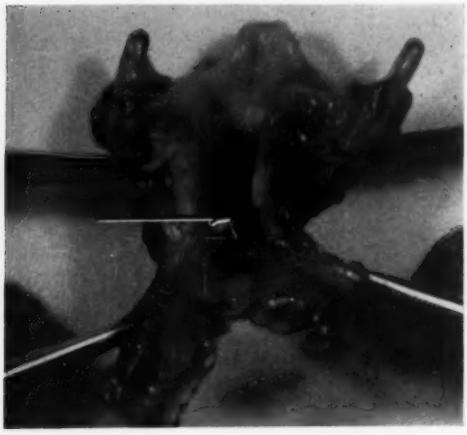

Fig. 5.—Cartilaginous deformity of the arch of the cricoid. The larynx is opened from posteriorly and the level of the stenosis is indicated by the arrow.

rent episodes of croup were the only suggestion of this condition, with repeated superimposed respiratory infections simulating laryngotracheobronchitis, although characterized by severe obstruction with minimal evidence of infection. In severe cases with progressive respiratory distress, tracheotomy becomes an urgent procedure. Fourteen of the thirty-four infants with congenital subglottic stenosis required a tracheotomy.

Mild stenosis usually disappears with growth of the larynx. In more severe cases, periodic dilatations of the larynx are performed to stretch the lumen to a more adequate caliber. This can be done without fear of resulting edema leading to complete obstruction of the larynx in patients who have been tracheotomized, but such therapy carries some risk if done without a tracheotomy. With an inflammatory component, adequate antibiotics, hydration and a humidified atmosphere are of utmost importance.

The clinical history of the infant whose larynx appears in Figure 4 is as follows:

P. G. was born on August 2, 1948. She had difficult, stridorous breathing from birth, which became more marked in the third week of life. On admission to the hospital on September 4, 1948, her rectal temperature was 99, pulse 160, and her respirations were stridorous at the rate of 40 per minute. Intercostal and suprasternal retractions were present. She was considered to have laryngotracheobronchitis and was treated actively for this for four days, but respirations did not improve. A tracheotomy became necessary on the fourth day and was performed over a bronchoscope. On exposure of the larynx, mild edema of the arytenoids and swelling of the subglottic region were noted. Except for a few critical episodes, when the tracheal cannula became plugged with mucus, the postoperative course was uneventful. Further endoscopic examination at a later date revealed a definite subglottic stenosis. The thought of a double aortic arch with tracheal compression was entertained, but was not supported by esophagograms. Periodic dilatations of the larynx were carried out during the ensuing year and she responded well to treatment and the tracheal cannula was removed one year after tracheotomy was performed. The patient has had no further respiratory difficulty.

Anomalies of the cricoid cartilage are responsible for some cases of subglottic stenosis. Two infants mentioned above had severe cartilaginous deformities which necessitated tracheotomy. The following is a case report of one of these two infants:

M. M. was first seen on April 9, 1950 at four weeks of age in extreme respiratory distress. He had had respiratory difficulty from birth. A lateral x-ray of the neck showed marked narrowing of the airway at the level of the cricoid cartilage. Exposure of the larynx revealed a bony-hard stenosis below the level of the true cords, aparently at the level of the cricoid cartilage, and efforts were made to pass a bronchoscope beyond this point to establish an airway. This was unsuccessful because of the firm resistance. As the infant became more cyanotic an attempt was made to pass a small metal aspirator through the tiny opening in the subglottic space, but this also met with failure. An emergency tracheotomy was performed and artificial respiration was administered, but the infant failed to respond and expired. Necropsy showed the glottic and supraglottic structures of the larynx to be normal. The cricoid cartilage was deformed and this deformity obviously was the cause of the obstruction. A shelf-like plate of cartilage, filling the convex inner surface of the arch of the cricoid cartilage extended posteriorly as a solid, rigid sheet, leaving only a small posterior opening (Fig. 5). In addition, hydrocephalus with complete closure of the foramina was disclosed.

CONGENITAL CYSTS AND LARYNGOCELES

Five cases of congenital cysts of the larynx have been seen in infants (Table 2). Two, reported previously,[13] accounted for respiratory obstruction and a muffled or absent cry in infants, each two months of age. Symptoms had been present since birth. The cysts originated in the right laryngeal ventricle and bulged into the glottic lumen, completely covering the right true cord (Fig. 6). They were filled with thick mucus; in one case a temporary trache-

TABLE 2.

SUMMARY OF FINDINGS IN PATIENTS WITH CONGENITAL CYSTS OF THE LARYNX.

NO.	NAME	AGE	SEX	SYMPTOMS	LOCATION	TREATMENT
1	E. B.	2 mos.	F	Hoarseness and dyspnea	Right laryngeal ventricle	Endoscopic removal
2	F. H.	2 mos.	F	Aphonia, dyspnea and cyanosis	Right laryngeal ventricle	Tracheotomy and endoscopic removal
3	H. W.	2 mos.	F	Stridor and gagging	Left aryepiglottic fold	Repeated aspiration
4	C. J.	1 day	F	Crowing respirations, severe dyspnea	Right laryngeal ventricle	Endoscopic forceps removal
5	P. M.	15 yrs.	M	Stridor and muffled voice since birth	Left aryepiglottic fold and vallecula	Aspiration

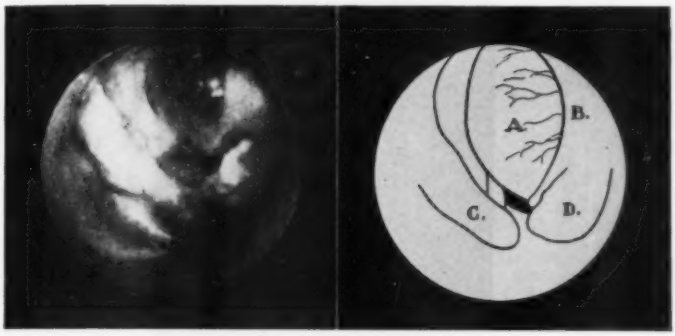

Fig. 6.—Congenital laryngeal cyst as seen through the direct laryngoscope. The line drawing on the right identifies the structures. A. cyst protruding from right laryngeal ventricle. B. Right false cord. C. Left arytenoid. D. Right arytenoid.

otomy was necessary after partial endoscopic removal, and in the second case endoscopic removal with cup forceps resulted in a normal cry and normal respirations without the necessity of a tracheotomy.

Three additional cases may be added to the previous report:

H. W., two months of age, was seen on January 6, 1947 because of stridor from birth and gagging during feedings. Moderate dyspnea and slight epigastric and suprasternal retractions were present and she had a muffled cry. Laryngoscopy revealed a large cyst in the left aryepiglottic fold, compressing the larynx and forcing the epiglottis to curl upon itself. The cyst was aspirated of two cc of thick, tenacious, mucoid secretion, resulting in collapse of the cyst and complete disappearance of symptoms. As it has refilled it has required periodic aspirations; each time the mother has noted the child becoming hoarse, she has returned for aspiration of the cyst as an out-patient. The procedure is accomplished rapidly without anesthesia and is accompanied by little trauma. Intervals between aspirations have gradually increased from one to two months to a period of eight months since she last required aspiration.

The fourth infant with a congenital laryngeal cyst, C. J., was admitted on December 5, 1952, at one day of age with crowing respirations since birth. The progressive respiratory distress had necessitated a tracheotomy at fourteen hours of age. Laryngoscopy revealed a grayish-yellow cyst similar in position to those in the first two infants. It appeared to arise from the right ventricle almost completely filling the laryngeal aperture. The cyst wall was removed with cup forceps and there has been no evidence of recurrence. Microscopic examination

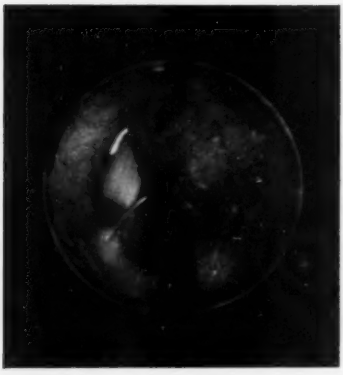

Fig. 7.—Direct laryngoscopic view of a large right-sided internal laryngocele. The sac involves the entire false cord and overhangs the glottis.

of the tissue which was removed showed the cyst to be lined with stratified columnar epithelium and to contain lymphocytes in its stroma. This histologic picture is consistent with congenital cysts of the larynx.

The fifth patient, P. M., a fifteen year old boy had had dyspnea, stridor and dysphagia since infancy. Symptoms had increased slowly and at the time of examination on April 12, 1952, he had considerable difficulty in breathing, talking and swallowing. Examination showed a large, round cyst, three to four cm in diameter on the left side of the pharynx, pushing the epiglottis to the right and apparently having its origin in the left aryepiglottic fold. Sixty cc of gelatinous fluid were aspirated with a heavy needle and the cyst collapsed to reveal a normal airway and normal vocal cords below. Recently symptoms have recurred and resection of the cyst seems indicated.

Most congenital cysts described in the literature are confined to the immediate neighborhood of the ventricular appendix.[14-18] It is probable that cysts are the result of simple disturbances in fetal development and not genuine embryonic malformations. Congenital cysts and laryngoceles have a similar development, but cysts do not communicate with the interior of the larynx. Laryngoceles admittedly become clinically perceptible only when swollen by air forced into them, or when filled with a collection of fluid; thus it is obvious that laryngoceles and cysts are often indistinguishable from each other. This is particularly true in adults, as Huckel[19] has

TABLE 3.
SUMMARY OF FINDINGS IN PATIENTS WITH LARYNGOCELES.

NO.	NAME	AGE	SEX	SYMPTOMS	SITE	TREATMENT
1	F. P.	51	M	Aphonia, dyspnea, tracheotomy	Bilateral	Laryngofissure and bilateral resection
2	J. C.	43	M	Hoarseness 3 months	Left	Resection supraglottically
3	C. M.	63	M	Hoarseness 1½ years	Bilateral	Incidental finding on laryngectomy for carcinoma
4	H. S.	55	M	Hoarse 4 months	Right internal and external	Supraglottic excision
5	A. F.	55	F	Hoarseness 1½ years	Right internal	Endoscopic drainage with biopsy forceps
6	L. T.	30	M	Hoarseness	Right internal and external	None
7	S. M.	50	F	Hoarseness 2 years	Right internal	Endoscopic incision and drainage
8	B. K.	58	F	Hoarseness one year	Left	Excision supraglottically
9	M. T.	56	M	Hoarseness and dyspnea 2 months	Right	Endoscopic drainage, recurrence, supraglottic excision
10	F. S.	61	F	Hoarseness, occasional dyspnea 4 months	Right internal	Endoscopic drainage
11	D. P.	33	M	Hoarseness; 1 year swelling in neck after singing	Bilateral internal and external	None
12	E. M.	39	F	Hoarseness 1½years	Right internal and external	Suprathyroid exposure and excision
13	R. B.	61	F	Hoarseness and dysphagia	Right internal	Endoscopic excision
14	A. C.	89	F	Hoarseness	Right internal	Endoscopic drainage
15	H. B.	63	M	Hoarseness 3 years	Bilateral internal and external	Endoscopic resection

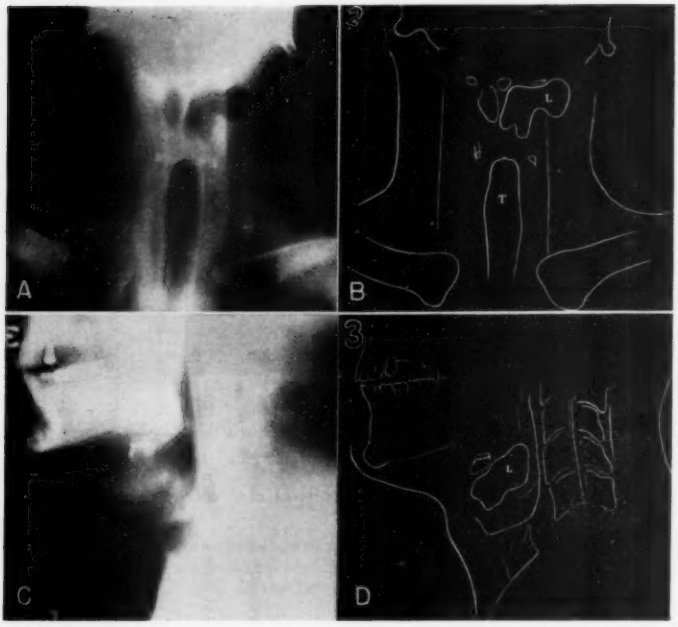

Fig. 8.—Antero-posterior and left lateral planograms of an internal and external unilateral (left) laryngocele. The line drawings clarify the significant structures. "L," the laryngocele, "T," the trachea.

already indicated. Congenital cysts are extremely rare in adults, probably because as hollow structures they fill and grow in intrauterine life and are, therefore, observed directly after birth.

Fifteen cases of laryngoceles have been observed (Table 3). Eight were in adult males, seven in females. The sacs were unilateral in eleven cases (Fig. 7) and bilateral in the remaining four cases. In nine in whom the laryngocele was unilateral it was on the right, in two on the left (Fig. 8).

These lesions are considered in the category of congenital anomalies in view of the above discussion. Their presenting symptoms were hoarseness and, in occasional cases, some dyspnea. One patient,

a singer, complained of a swelling in the neck after singing which gradually subsided with rest. In six patients the cyst was drained by uncapping the superior surface of the false cord with biopsy forceps. In one additional patient this technique was used but the cyst recurred and consequently it was removed through an incision along the superior border of the thyroid cartilage. This approach was used in four additional cases and in a sixth patient, bilateral laryngoceles were removed through an external thyrotomy approach. In one case bilateral laryngoceles were observed as incidental findings in a laryngectomy specimen removed for carcinoma of the larynx. Two patients have remained untreated, having been seen for diagnosis only.

DISCUSSION

The primary differences between the infant and adult larynx are:[20, 21] 1) size; 2) the tissues of the infant larynx are softer; 3) the infant larynx is placed higher in the neck; 4) the axis of air entry is straighter in the infant larynx; 5) the laryngeal lumen is more funnel-shaped in the infant than in the adult. Negus[22] mentions that the infant cricoid cartilage is somewhat funnelled and that the antero-posterior diameter of the larynx is relatively greater in comparison to that of the trachea than in later life, at which time the cricoid is ring-shaped.

The symptomatology in the group of cases herein presented did not vary greatly. A weak or absent cry in an infant at birth suggests a laryngeal anomaly in spite of the fact that respirations may be unimpaired. However, in the infant who has dyspnea, stridor, or cyanosis, the character of the cry becomes of great diagnostic importance. The muffled, pharyngeal quality of cry of the infant with a thyroglossal duct cyst[23] or other pharyngeal obstruction is quite characteristic. An infant with a laryngeal (glottic) web generally has some dyspnea and indrawing in the suprasternal notch and epigastrium in addition to the weak cry, but this combination is by no means indicative of the diagnosis since it is often noted in infants with subglottic stenosis. Similarly, the loud, stuttering, crowing inspiration which characterizes congenital laryngeal stridor could by no means be considered diagnostic in itself since infants with bilateral recurrent laryngeal nerve paralysis and those with tracheomalacia, alone or associated with a vascular anomaly compressing the trachea had an identical sounding stridor.[24] For this reason, a diagnostic routine is established which, in addition to the history and physical

examination, consists of antero-posterior x-ray studies of the chest and neck, and particularly the lateral x-ray of the neck with the arms down and back and the head up and forward to obtain as much visualization of the trachea as possible. Fluoroscopic studies of the esophagus with barium or lipiodol as a contrast medium are often indicated as well to rule out possible compressing vascular anomalies or other anomalies of the tracheobronchial tree.[25]

Direct laryngoscopy is the only manner of inspecting the infant larynx and therefore is the most important single diagnostic procedure. It may be done with small laryngoscopes without administering an anesthetic to the infant. In acute laryngeal obstruction the instrumentation may precipitate complete respiratory obstruction; therefore, in the acute emergency direct laryngoscopy should be attempted only if the diagnosis cannot be established otherwise or if surgical relief of the obstruction through direct examination and aspiration, intubation, or tracheotomy is being considered. Instrumentarium should be ready for this eventuality when a direct examination of the obstructed larynx is contemplated. The difficulties of direct laryngoscopy in infants are due to the small size of the larynx and the curled, short, slippery, omega-shaped epiglottis. The larynx is easily displaced, and there is a decided tendency toward spasm of the larynx as the laryngoscope is introduced. This often makes visualization of the true cords and of the glottic airway difficult. The procedure must be done rapidly to avoid instrumental trauma. Treatment in this series has been conservative. Dilatation of laryngeal webs and subglottic stenosis and aspiration of laryngeal cysts rather than extensive external surgical procedures has, for the most part, given reasonably good results. Once the diagnosis of a congenital laryngeal anomaly in an infant was established, it was felt that the surgical procedures, other than endoscopic, could be postponed and approached more successfully when the infant had gained maturity. The exception to this was a tracheotomy if respiratory obstruction was severe or frequently recurring.

In a recent analysis of lesions necessitating tracheotomy in infants under one year of age,[26] twenty-seven of the total of sixty-two cases (44 per cent) required tracheotomy because of a congenital laryngeal anomaly, and nine (14 per cent) in addition were tracheotomized because of other congenital anomalies that necessitated extensive surgical repair. Only nineteen or 31 per cent of the sixty two cases were tracheotomized for inflammatory disease; the remain-

ing seven (11 per cent) had neoplastic disease of the neck or larynx which obstructed the airway directly or by compression. This is in contradistinction to infants and children above one year of age in whom inflammatory disease was the etiology for which a tracheotomy was performed in approximately 90 per cent of cases. Of further interest was the fact that while the incidence of tracheotomy in infants for inflammatory disease such as acute laryngotracheobronchitis has steadily decreased over a period of fifteen years, the incidence of tracheotomy for other causes, such as congenital anomalies, laryngeal paralysis, polio, skull fracture, burns, tetanus, etc. has steadily increased.

Two groups of patients with laryngeal disease at birth are not included in this summary of congenital laryngeal anomalies. One is the group of laryngeal paralysis, either unilateral or bilateral, which were associated with cerebral agenesis, cervical meningomyeloceles, or extensive cardiovascular anomalies involving the left recurrent laryngeal nerve. The second group are the tumors of the larynx discovered at birth or shortly thereafter because of the respiratory obstruction they produced.[27]

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XLVII

A STUDY OF LYMPHOID TISSUE OF THE NASOPHARYNX

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In the course of the study being carried on at the Winthrop Foundation of the Massachusetts Eye and Ear Infirmary into the causes and treatment of hearing impairment, we found a significant number of children in whom intermittent tubal closure appeared to be related to recurrent adenoidal growth. In many of these young patients, moreover, neither surgery nor postoperative x-ray treatment of the lymphoid tissue put a stop to regrowth. We began to ask ourselves whether these cases required special surgical techniques. Was allergy perhaps at the bottom of the trouble? What could be done with irradiation? What kind of irradiation—x-ray or radium? We soon found, in searching for the answers to these questions, that we would have to begin at the very beginning and find out all there was to know about nasopharyngeal lymphoid tissue. What is lymphoid tissue? What purpose does it serve in the organism?

A survey of the literature made it clear that we were dealing with an extremely complex subject. Much of it was conjecture; a good deal of it, controversial. Even the most qualified students of lymphoid tissue confessed that many of the fundamentals were a mystery. Most involved of the myriad aspects of the problem, perhaps, was the endocrine question. Through that particular maze the otolaryngologist had best not wander without the guidance of the endocrinologist. Certain other aspects of the study could best be approached with the help of the pediatrician.

These areas still remain to be explored. At this juncture we have not got beyond a thorough survey of the literature, some histological studies which may be of interest, and an evaluation of the results that have been claimed for irradiation. Some of this work

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From the Winthrop Foundation, Massachusetts Eye and Ear Infirmary, Boston. Aided by a grant from Mr. Frederick Winthrop.

has already been done, notably so by Dr. Schenck[14] and others at the symposium held by the Academy of Ophthalmology and Laryngology in 1950. But it seems to me that the fundamental facts involved in a study so complex as this bears repeating.

The problem of nasopharyngeal lymphoid tissue resolves itself, as far as the otolaryngologist is concerned, into two distinct categories: the rhinological, and the otological.

A mass of adenoid tissue may obstruct the nasal airway and interfere with its function, often resulting in some rhinological disorder. When the mass is removed, the difficulty usually is cleared up. The tissue rarely recur in sufficient amount to again obstruct the airway; in any case, a second removal usually provides a permanent solution to the problem.

When the mass of adenoid tissue encroaches upon the tube simply by contiguity, any interference with tubal function can similarly be handled by removing the mass. This must be true of the great majority of patients with tubal disorders, to judge by the excellent results achieved in the great majority of adenoidectomies.

However, when tubal dysfunction recurs after operation, either following or in the absence of upper respiratory infection, then we know we are dealing not with a mere mass of lymphoid tissue mechanically obstructing the tube by contiguity, but with actual residual lymphoid tissue in the fossae of Rosenmuller, within the tubal orifice or on the torus or the salpingopharyngeal or salpingopalatine bands. This is the lymphoid tissue that poses the problem.

Now it has been conceded that lymphoid tissue everywhere in the organism is structurally and functionally the same. Therefore we can assume that what is true of lymphoid tissue, per se, is true of the lymphoid tissue of Waldeyer's ring.

HISTOLOGY

What is lymphoid tissue? Drinker and Yoffey[6] give the most concise definition of it as a mass of free cells, the vast majority of them lymphocytes of various sizes, together with a supporting framework of reticulum cells and of fibrous, elastic and sometimes muscular elements. Aschoff[1] differentiated between the tissue of the lymph nodes, which has afferent and efferent lymphatic vessels; the tissue in the mucous membranes, which has only efferent vessels; and the

lymphoid tissue of the spleen which has neither. We know, of course, that even within Waldeyer's ring itself we find tissue with and without glands opening into the crypts.

In the course of our investigation, we had to determine whether the masses we saw in the nasopharynx were actually hypertrophied lymphoid tissue, or merely edema resulting from infection or allergy. Therefore, at operation, the tissues were carefully removed from specific areas, such as the tori, fossae of Rosenmuller, the salpingopharyngeal and salpingopalatine bands, and studied histologically.

Sixty-six patients were chosen who were being operated on for ear symptoms, with bouts of deafness, associated with acute suppurative or acute secretory otitis. All of them when first examined had measurable hearing loss, but hearing improved following inflation of the middle ear in most of them, indicating reversibility of the loss. Primary tonsillectomy and adenoidectomy was carried out in 41; primary adenoidectomy alone in 2; secondary tonsillectomy and adenoidectomy in 1; and secondary adenoidectomy in 22.

There were removed 549 separate pieces of tissue, varying in size from 3-4 mm to half a centimeter. Well-defined secondary nodules were found in 437 of the pieces; 112 pieces proved not to be lymphoid tissue. From 55 of the patients, the tissue was removed from the torus; in 7, from the lateral band; and in the remaining, from the fossae of Rosenmuller. Secondary nodules were found in 79.6 per cent of the tissue; it is quite possible that if serial sections had been made, the percentage might well have been even higher. These cases represent true lymphoid tissue hypertrophy, and it was intensely active tissue, as judged by the great number of secondary nodules.

Losanow[11] states that lymphoid tissue is present in the embryo. According to Drinker and Yoffey, it can be found in the human throughout life. Scammon[13] found that no other body tissue, except the neural, develops so rapidly in the period from the first few months of life to the sixth year. The maximum peak is reached about the twelfth year, according to Scammon; then it begins to decrease, at first markedly, then more gradually until a more or less stable level is reached. Nevertheless, Kelemen[10] found well-developed, hyperplastic tonsillar tissue as late as the ninth decade of life. This "age involution" is to be distinguished from what Doughterty[3] calls "acute

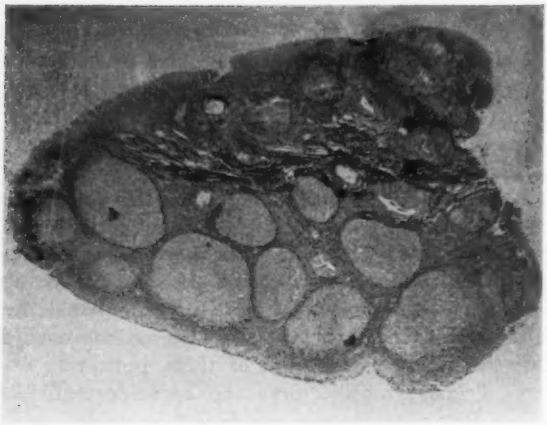

Fig. 1.—Photomicrograph. One lobule, tightly packed with follicles. x 20 Heidenhain.

involution," which occurs abruptly, regardless of age, in response to a number of physiological and pathological stimuli.

PHYSIOLOGY

What is the function of lymphoid tissue? It was largely on the basis of clinical observations that lymphoid tissue was accorded an important role in the body's defense reactions. Virchow[17] in 1860 was the first to formulate the concept that the lymph nodes act as barriers against infection, a concept that remained unchanged for the better part of a century. And once the concept was accepted for lymph nodes, it was extended to the other lymphoid tissues, the tonsils and other nasopharyngeal aggregates coming to be looked upon, in Drinker and Yoffey's words, as "somehow guarding the gateway to the alimentary canal."

In more recent years, the defense theory has been elaborated to include: (1) the concept of lymphoid tissues as reaction centers where undesirable material is filtered out of the circulation, and (2) the postulate that antibody formation takes place in the lymphocyte.

The precise site of antibody formation has been debated vigorously. Recent studies favor the lymphocyte rather than the reticulo-endothelial cell, as Metschnikoff's followers believed.

Skoog's[16] experiments convinced him that under experimental conditions antibodies can be produced in the tonsil, but not to a degree comparable with that possible in other organs of the reticulo-endothelial systems. He concluded that the physiologic function of the tonsils was not to immunize the organism in the ordinary sense but to stimulate the reticulo-endothelial system to produce antibodies.

More recently, Ehrich and Harris,[7] extending the work done earlier by proponents of Bunting's theory that the lymphocyte was the site of antibody formation, satisfied themselves that cellular response within the lymph nodes during antibody formation is chiefly lymphocytic. These writers say that, if their reasoning is correct, the lymphocyte goes into action only after bacteria and other formed antigens have been properly prepared by the action of micro- and macrophages. It may be that antibodies are formed by the cooperation of lymphocytes with polymorphonuclear leucocytes and macrophages. This concept, they reason, would make clear why reticulo-endothelial blockage may or may not interfere with antibody formation.

Doughterty, Chase and White[4] concluded from certain of their experiments that antibodies are concentrated in the lymphocyte. And in 1952, Tore Wesslén,[18] in experiments undertaken to determine if the lymphocyte was a carrier or a producer of antibodies, concluded that lymphocytes in the form in which they enter the blood stream do not contain any antibodies but are capable of producing them.

Now, what of the function of nasopharyngeal lymphoid tissue? The literature on this score is limited. According to Forster,[8] the faucial tonsil is, in conjunction with other lymphoid tissue of the pharynx, considered to be a protective barrier against microbic invasion. He reminds us that Hellman observed reaction to invasion in the secondary follicles, and that Waldapfel and Grossman confirmed that the tonsil has a protective function. Yoffey believed that the lymphocytes are very likely concerned with the active growth processes of childhood, the lymphoid tissue acting as a storehouse of primitive wandering mesenchyme to supply various tissues as needed.

Wright[20] also reviewed the opinion on the tonsil's function, and attempted to conciliate the evidence for the barrier concept with

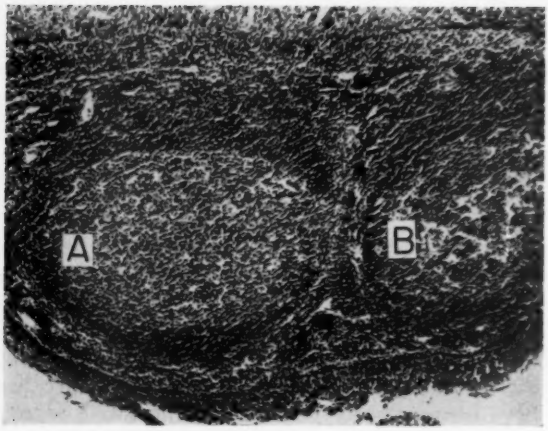

Fig. 2.—Photomicrograph. Lobule containing only two follicles—one dense, one loose; edema? x 60 HE.

the clinical observation that the tonsil often becomes a focus of infection and has to be removed. He suggests that an evolutionary process takes place. The nasopharyngeal lymphoid tissue, originally adequate as a defense against microbic invasion, proves unequal to the assaults that follow in the wake of civilization, which exposes man to all the dangers of crowded urban life.

But Wright himself reminds us of Harry Barnes' warning against "flights of fancy in theorizing on the function of lymphoid tissue," and we might do better to get down to facts.

ANATOMY

The most significant characteristic of the nasopharynx as it effects the lymphoid tissue is the great variation in size and conformation. Dickson and McGibbon[2] cite the work of Escat (1901) and of Moure and Lafarelle (1901), who described the many skeletal and other variations of the nasopharyngeal cavity. Escat pointed out that in the dolichocephalic skull, the nasopharynx is narrow transversely, with a long antero-posterior axis; in the brachycephalic skull, the nasopharynx is wide transversely and shallow from front to back.

Adding to these earlier studies their own careful measurements, Dickson and McGibbons concluded that "there is no 'constant' shape and no 'constant' measurement for all pharynges."

One very important factor determining the size and shape of the nasopharynx is the highly variable size of the torus and of the degree to which it projects into the nasopharynx. I was extremely skeptical when I first saw Kostanetsky's pictures showing variations of the tube; I now humbly concede the accuracy of his observations.

Indeed, I have observed the tori to be so hypertrophied as to close off the posterior choanae, completely obstructing the view of the rest of the postnasal space.

The fossae of Rosenmuller also vary widely in conformation. The entry may be a mere slit, measuring only a few millimeters, so that we see the fossa itself only when the torus is retracted laterally; or it may be so deep that one cannot view it in its entirety even on retracting the torus. On the other hand, the fossa may be so shallow that all of it can be seen easily merely by retracting the soft palate.

I have no doubt that the great variation to be found in the local anatomy is what accounts for the indifferent results achieved in the ordinary or blind adenoidectomy.

PATHOLOGY

To understand the impact of infection and allergy on nasopharyngeal lymphoid tissue, one must delve a little deeper and investigate capillary permeability. Capillary permeability remains for the most part a mystery. But enough is known about it to clarify what happens when infection or allergy affects lymphoid tissue.

We know that the return of cellular fluids to the circulation takes place either directly into the blood or through the lymph capillaries. According to Doughterty,[3] most of the fluid and the relatively simple compounds of low molecular weight are directly absorbed into the circulation through the blood capillaries. Particles of larger molecular weight, mostly the blood proteins, have to go through the lymph capillaries. When infection is present, not only is capillary permeability increased, but the products of infection bring about stasis, interfering with both blood and lymph flow. With allergy, edema results from the local action of the histamine or histamine-like substance on the tissues.

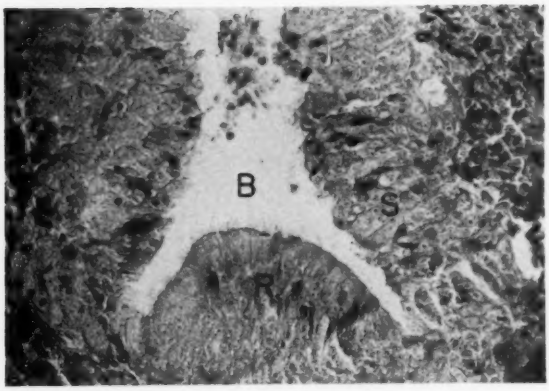

Fig. 3.—Photomicrograph. Respiratory epithelium at bottom of crypt; (B) crypt bottom, (R) respiratory epithelium, (S) stratified epithelium of crypt wall. x 460 Heidenhain.

Drinker's[5] experiments, which have an extremely significant implication for us here, showed that the nasopharyngeal lymphoid tissue need not be overwhelmed by an acute infection to develop edema and hyperplasia. These effects could be marked even when only a few bacteria and viruses of low virulence are present in the mucosa capable of surviving and multiplying. What this means is that the torus and tissues of the fossae of Rosenmuller invaded by these agents become a shock area. There is basis for this hypothesis in Rowe's[12] statement that " . . . though sensitization of all cells of the body may occur, allergy usually evidences itself in vascular, connective or lymphoid tissue." It could very well be that the tissues harboring these noxious agents become sensitized, become the shock tissues in the sense in which Selye[15] uses the term in his concept of the alarm reaction and the general adaptation syndrome.

How the picture produced by infection can be positively differentiated from what we see in allergy, I do not know. But a clue is to be found in the duration of symptoms, and in their response to treatment. If there is infection, the reaction to it in lymphoid tissues will clear up as the infection subsides. We must remember, however, that the hypertrophied lymph nodules will remain. In an

allergic reaction, the edema will persist much longer; when it does disappear, the remission will be brief, and it will recur.

Allergists, and some otologists, believe that underlying allergy accounts for all alterations in the lymphoid tissue of Waldeyer's ring. Schenck[14] believes this conclusion to be fallacious. Certainly, one cannot blame all lymphoid alteration here on allergy. But I cannot but conclude, after seeing so much recurrence even after the most thorough surgery, that allergy plays a cardinal role. This belief is strongly supported by the number of cases in which improvement is seen following allergic management in these patients.

ENDOCRINE FACTOR

I have said that the endocrine aspect of this problem is still to be explored with the help of the endocrinologists. We have learned enough about it, however, to conclude that this is perhaps the most important avenue of research in the study of lymphoid hyperplasia. The work now going forward in exploring the relationships between lymphoid tissue growth and involution and the endocrine glands—the pituitary, adrenal, thyroid—promises to provide us with the key to effective treatment.

It has been shown that adrenocortical secretion brings about lymphoid tissue involution. Some of the involuting effect of irradiation appears to be endocrine- mediated; so, too, the involuting effect of inanition. White believes that all the factors inducing involution —including nutrition, chemical agents like nitrogen mustard, physical factors like heat, cold and atmospheric pressure—may be mediated by the genetic factor.

I do not propose to go into the many ramifications of this highly complex problem here. But I refer to this particular aspect of the subject merely to indicate its complexities and obscurities.

I would like to say one thing more, however. It has already been demonstrated that in allergic rhinitis, startlingly successful results—though too often temporary—can be achieved with ACTH and cortisone. It stands to reason that with further purification of these substances, and with accumulating clinical observation of the results achieved with them, ACTH and cortisone may be successfully applied to nasopharyngeal tissue hyperplasia in the future.

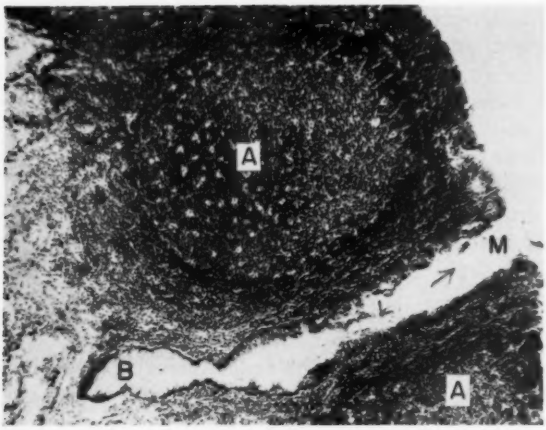

Fig. 4.—Photomicrograph. Opening of gland into crypt bottom flushing crypt content against mouth of crypt. (A-A) follicles, (B) bottom of crypt, (M) mouth of crypt. Arrow shows direction of current of glandular secretion flushing the crypt. x 60 HE.

IRRADIATION

The treatment of lymphoid tissue hyperplasia by irradiation goes back to Heineke's discovery in 1903 that roentgen irradiation causes lymphoid tissue to involute. Since then, we have seen the early enthusiasm for reducing the tonsil by x-ray treatment wane, and a new enthusiasm take its place—the use of radium to reduce lymphoid hyperplasia in the nasopharynx. The history of irradiation treatment of the nasopharyngeal lymphoid tissue goes into more than two thousands titles in the literature. It can be summarized in a few sentences.

We know now that the attempt to reduce the tonsil by x-ray failed because irradiation is not effective for encapsulated lymphoid tissue like the tonsil, but, rather for the scattered lymphoid tissue that eludes even the most thorough surgery. Radium treatment for this purpose is still being argued. You are all familiar with the early reports of its results. On the debit side of the ledger is an increas-

ing documentation of the opinion that radium yields less impressive results. Where controls have been used, untreated cases, it is reported, have fared as well, ultimately, as those treated with radium.

We at the Massachusetts Eye and Ear Infirmary, from the beginning, preferred the greater accuracy and safe of x-ray. I have already referred to the Dickson-McGibbon study, in which measurement of the nasopharyngeal cavity made it clear that anatomical variations were too great for accurate positioning of the radium applicator. At the Winthrop Foundation we had come to a like conclusion.

Not that we hold any brief for x-ray treatment. In the course of the twenty and more years of my experience with it, I have never seen a lymphoid mass resolve following its use. This is in keeping with what we know, now, happens to the lymph follicle.

The immediate effect of irradiation is on the secondary nodules, and manifests itself in these three stages: first, cessation of proliferative activity; second, conspicuous scavenger activity during which the destroyed cells are removed; and third, depending on the dosage used, the return of proliferative power. It must return, unless treatment has gone beyond the limits safe for non-neoplastic tissue. Naturally, the greater the dosage, the quicker the ensuing destructive process. But eventually regeneration does occur. Schenck's studies have demonstrated that irradiation by any means—x-ray, radium, ultra-violet rays—produces the same effects.

This is why I believe that irradiation can never replace surgery as a means of removing scattered lymphoid tissue. Not that surgery is by any means the perfect solution. Indeed we know that in some children, operation seems only to increase the tendency of hyperplasia to recur. Then there is the possibility that when it does recur, it will be in an area even less desirable—the lateral bands, the tori or the fossae of Rosenmuller.

But we still operate because we know that in many instances surgery will permanently exhaust the regenerative properties of lymphoid tissue. And quite often this is enough to relieve tubal obstruction. True, the same claim is made for irradiation, and for allergic management. Perhaps the answer is to use all three measures.

Surgery has the advantage over irradiation in that it can actually remove the mass of lymphoid tissue. What irradiation apparently

does is to inactivate the lymphocytes and, as Schenck suggests, to reduce the edema by increasing lymph flow. This result is, only ephemeral, but if normal tubal function can be restored, even temporarily, we are that much ahead.

Our management of lymphoid regrowth resulting in tubal closure depends on the patient's history and what we find at operation under direct vision. If hearing has been impaired as a result of tubal closure following upper respiratory infection but has returned to normal after one or two inflations, we remove the obstructing tissue. No follow-up management is given. Should the tubal occlusion recur after an upper respiratory infection, and nasopharyngeal examination show the vault to be free of lymph nodules, we advise irradiation: 600 r in three treatments; 100 to each side through an intraoral cone or over the lateral neck.

If, on the other hand, a patient has a history of recurring tubal closure without upper respiratory infection, and we find lymphoid tissue in the areas described, we first remove the tissue thoroughly by surgery and administer x-ray treatment within two weeks of the operation. If this fails to bring about the desired result, we advise allergic studies, regardless of whether the patient shows clinical evidence of allergy or not.

Where the patient is definitely known to have a history of allergy but has not responded to allergic therapy, we remove the lymphoid tissue surgically. If there has been no treatment for allergy, such treatment should be the first step. If the patient does not improve, we resort to surgery. Whether or not irradiation is given depends on his postoperative course.

CONCLUSION

What has been said so far adds up to few conclusions. We know this much: When a mass of nasopharyngeal lymphoid tissue interferes with nasal or middle ear function by imposing an obstruction, its removal almost always restores normal function. When tubal obstruction is the result of hypertrophy and edema of the lymphoid tissue on the tori, the fossae of Rosenmuller or the lateral bands extending from the torus to the palate and lateral pharynx, the obstruction can best be coped with by surgical removal of the excess tissue, under direct vision. Not infrequently further treatment such as sup-

plementary irradiation may be necessary to control postoperative recurrence of tubal closure.

Grateful acknowledgment is made of the histological interpretations made by Dr. George Kelemen and the translations and other bibliographic assistance given by him, and to Miss Dorothy Linden, technician at the Massachusetts Eye and Ear Infirmary.

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XLVIII

SOME PRACTICAL CONSIDERATIONS CONCERNING RESPIRATORY ALLERGY

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PHILADELPHIA, PA.

The 75 years which mark the span of the American Laryngological Association have been the most significant in the whole history of medicine. They have not only witnessed the breath-taking advances in the basic sciences and in the general knowledge of the causes and management of disease, but they have seen the growth and development of this Association's specialty almost from its beginnings to its present high estate. Bacteriology brought asepsis, and anesthesiology made possible new surgical techniques. More recently, antibiotics and bacteriostatic agents made unnecessary many operations that once took most of one's time, but, as Lempert[13] has recently emphasized, they also made possible an effective operative approach in new fields, such as modern labyrinthine surgery.

The word "allergy"[16] was coined within the lifetime of most of the members of this Association. The development of that subject has been known to, and shared in, by many of you, and you all know how great has been its impact upon the practice of your speciality, since the respiratory tract is the site of the commonest, most diversified and some of the severest manifestations of hypersensitivity. The fact that my interest has centered largely on allergy in the respiratory tract has perhaps been responsible for the invitation to appear on this program. I realize keenly how presumptuous it is for me to discuss a topic with whose practical aspects this group is so thoroughly familiar. I can only hope that from my experiences during 40 years in the field of respiratory allergy I have gleaned a few points that may be worthy of your notice.

We are most likely to fall into scientific error when for the moment we lose sight of basic principles as we follow some current enthusiasm in a very proper search for progress. If I may borrow in a limited sense the much broader philosophy in one of Kipling's

poems, we are inclined to heed the glittering promises of the gods of the market-place, rather than the simple truths of the gods of the copybook headings. Yet Kipling[12] makes his point in the opening stanza:

> "As I pass through my incarnations in every age and race,
> I make my proper prostrations to the Gods of the Market-place.
> Peering through reverent fingers I watch them flourish and fall,
> And the Gods of the Copybook Headings, I notice, outlast them all."

And so I would like to stress certain principles the slighting of which has been responsible for our commoner mistakes.

The importance of allergy in all phases of clinical medicine needs little emphasis before this audience. Fifteen per cent of the population at some time in their lives will manifest a major form of allergy, such as seasonal and perennial allergic rhinitis, asthma and eczema, and another 25 per cent will show lesser evidences of hypersensitivity. The proportions are even higher in the practice of otorhinolaryngology.

We must be reminded, however, that the allergic patient is a special kind of individual, with an inborn, ineradicable defect. What he has inherited is not a particular disease, such as hay fever, nor a specific sensitivity, such as that to ragweed pollen, but a much greater-than-normal ability to become sensitive to things in his environment; he is born that way and he so remains until the day he dies, and all the medical experiences of his lifetime may be influenced and modified by that fact.

On the other hand, the specific sensitivity to this or that substance may be of limited duration, lasting for months or a few years. The pattern of a patient's sensitivites is therefore not a fixed and constant thing. New sensitivities come and old ones go, so that the same clinical complaint may have different allergenic causes at different times in the patient's life. This is of great importance in solving the problem of recurrences of a complaint after long periods of relief.

Moreover, the part of the body that reacts to the allergen, the shock organ, may change, with or without a change in sensitivities, So a patient may have eczema in infancy from wheat or house dust, nasal symptoms in adolescence, and transient hoarseness, or paroxysmal nonproductive cough, or asthma (depending on whether larynx,

trachea or bronchial tree is the shock organ) in middle years from the same or other causes, and eczema again in old age from yet newer sensitivities. Only one thing does not change: the easy sensitizability of the allergic individual.

It is important to consider how this individual acquires new sensitivities, because this knowledge can make it easier to discover offending allergens, and what is more important, can help the physician to prevent sensitization in the first place. These factors are undoubtedly at work: 1) overexposure of a body surface (skin or mucosa) to allergens; 2) injury to a body surface, whether by chemical irritation, infection or mechanical trauma, rendering that surface more permeable to, and therefore sensitizable by, those allergens which happen to be present. This accounts for the frequent development of respiratory allergy in the course of such severe and prolonged infection of respiratory mucosa as occurs in measles, influenza, whooping cough and various viral pneumonias. Moreover the offending allergens are more likely to be those to which the patient is increasingly exposed during such an illness, namely the things in his bedroom: feathers, wool, house dust.

This principle justifies the restriction to a minimum of exposure to potent allergens in the case of allergic children and also the children of allergic parents. This is particularly true and practical in relation to inhalant allergens, because, to a considerable degree, we can control our environment. In the bedroom, this means rubber-foam pillow and mattress, old hard-weave cotton blankets covered with cotton sheeting, bare floor, with at most a washable cotton rag rug at the bedside, smooth painted walls. It also means no feathers or animal hair in bedding, no upholstery, no unnecessary hangings in the bedroom. Nor should that room be contaminated by the introduction of dust from the rest of the house by a hot-air heating system or by the use of insecticidal sprays. This principle can be extended to include the selection of toys and pets in childhood, cosmetics in adolescence, and vocations in adult years. I have discussed this subject extensively elsewhere.[5]

In 1926,[4] I first called attention to the fact that hay fever often begins in the year in which an operation of election was performed on an allergic individual during a pollen season, and I then urged that such operations in the allergic subject be carried out at least a month before pollen appears in the spring, or be deferred until after frost in the fall. While this suggestion has received fairly gen-

eral acceptance, there are still many unpremeditated exceptions, especially in children, whose tonsils are so frequently removed just after school closes in June, when the grass pollen season is at its height, or else just after they return from summer camp on August 31st and before school opens, when ragweed pollen counts are at the peak.

The next principle is introduced with a modicum of malice aforethought. It applies not only to allergy but to infections in the respiratory tract. I constantly stress it in my teaching of medical students, internes and residents, and I bring it to the attention of physicians whenever opportunity offers, even of those who specialize in disorders of that system, albeit some above, some below the larynx. The whole respiratory tract must be considered as a unit. Disease in one part, whether allergic or infectious or both, is commonly associated with involvement of another part. As you well know, the one may be symptomless, with the result that the other gets all or most of the attention. Yet, regardless of which came first, treatment of the silent lesion must accompany that of the obvious one in order to achieve a lasting result.

The complexity of allergenic etiology is nowhere more marked than in the respiratory forms of hypersensitivity. In the skin, allergic disorders are preponderantly based on contacted substances; in the digestive tract, on substances swallowed. But in the respiratory tract, one must reckon in the same case not only with inhalants, but with things that are swallowed, and also with bacteria. This is true even in many patients with purely seasonal symptoms, due primarily to pollens, but often aggravated by sensitivity to substances that are perennially present. It must be emphasized that this calls for a more extensive allergic survey in many cases of respiratory sensitivity than is now made. Thus, the patient with strictly seasonal symptoms should be tested not only for the pollens that occur in that season, but also for a) the pollens of known significance, in other seasons, in that area, b) the commoner mold spores there prevalent, and c) those animal epidermal substances, cosmetic ingredients, house dust and similar inhaled allergens to which he is perennially exposed in his particular environment. The patient with perennial symptoms of respiratory allergy must be checked routinely also for sensitivity to foods as well as inhalant sensitivities.

The number of potential inhalant allergens is increasing at amazing speed. In modern industry such varied contacts are exceedingly

common, and the products of industry can also contribute to the allergic hazards in the home. It has long since become inadequate to define a patient's occupation in a word or two. A detailed record of his working day may have to be supplemented by a visit to his place of employment to uncover the causes of his trouble. Indeed, it is in this diagnostic phase of our problem that the allergist serves his greatest purpose: skin tests can be done by any technician; it is the allergist's knowledge, based on training and experience, that leads to the proper selection of things to be tested and to a sound interpretation of the results obtained.

In 1921[3] I called attention to the role of house dust in the etiology of asthma. Today it ranks as one of the most important factors in allergic conditions of the respiratory tract. In spite of much intensive study by many investigators over the years, we still have no final answer as to the nature of the allergen or allergens in house dust. Occasionally it is possible to identify a specific component of a given house dust, such as a certain animal epidermal substance, as the thing to which the patient is sensitive. But as a rule this is not true.

The fact that an extract of some house dusts will give positive skin tests in a considerable number of patients with respiratory allergy has led to the view that such dusts must contain an allergen common to them all. It has further led to the view that several dusts from different homes together contain most or all of a few important allergens that any house dust might contain. Above all, it has led to the practice, by many allergists, of testing patients with only the extract of a pooled lot of dust collected, say, from the 24 units of an apartment house, and then of treating with such a so-called stock dust extract those patients who give a positive skin test to it. This, I contend, is fallacious, for the following reasons:

What is house dust? What is hash? Whatever is available to go into it. The dusts of houses are almost as individualistic as the people who live in them. To be sure, some ingredients in the way of furniture and upholstery materials may be common to many houses, and if they are good antigens, can be responsible for many common sensitivities. I once tested with the extract of a house dust that was the cause of a certain patient's asthma a series of 125 other asthmatics. No less than 26 of them reacted positively. But some ingredients (a rug of unusual origin, a mold that grows only in few

cellars, a rare varnish) may occur in only few houses. Thus, I also tested one patient's offending dust in 44 other asthmatics without getting a reaction in any one.

If a stock dust extract from an apartment house produces a positive test in a patient living in Unit Number 6, this could be due to something in the dust of Unit Number 24, but to which the patient in Number 6 is not exposed. To treat him with this stock extract would be an illogical treatment of a falsely positive laboratory test. Or it could happen that a false negative would result in a patient, actually sensitive to the dust of his own home, but not reacting to the extract of a stock dust in which his own dust was too much diluted by the addition of dusts from 23 other dwellings.

Some nevertheless defend the stock dust procedure on the ground that it is more convenient. Now it may be inconvenient, but it is never impossible to get an adequate dust collection from any patient's environment. As for the logic of the convenience of the stock dust extract, I am reminded of the drunk who was seen one night groping about on his hands and knees at a street intersection under the arc light. A passer-by asked: "What are you looking for?" "I losht my watch." "Where did you lose it?" "Over there under the treesh." "Then why are you looking here?" "The light'sh better."

Little need be said about the role of pollens in the etiology of respiratory allergy. Current practice is generally adequate and proper. Patients are no longer tested or treated to any extent with insect-carried pollens that play little or no part in the production of their symptoms. Attention is however called to one important cause for error: the failure to reckon with pyrethrum sensitivity. Skin sensitivity to this substance is almost as common as that to ragweed, and often in the same individuals. Long used as an insecticide, pyrethrum is more frequently encountered than ever before, because of its inclusion in most insecticidal mixtures and sprays, notably the various DDT preparations for use in households, hotels, theatres and the like with heavily carpeted floors.

Mold sensitivity, on the other hand, needs more consideration than it now receives from many physicians, especially along the eastern seaboard. Not only are mold spores present in large concentration in outdoor air in mid-summer, particularly in July, but they can be a source of perennial trouble in individual houses. A damp cellar is the prolific source of such spores, and even more important is the

increasing number of hot-air heating plants which, alleged filter devices notwithstanding, see to their distribution to all parts of the house and in most seasons. Diagnosis and management of mold allergy are analagous to those of pollinosis.

Food sensitivity can play a part in any of the perennial manifestations of respiratory allergy. This fact is generally accepted with regard to asthma, but there are rather frequent oversights as to its role in nasal symptoms.

Bacteria are involved more frequently and more significantly in allergic conditions of the respiratory tract than in those of any other part of the body. In most patients with perennial symptoms and in many who have ragweed pollinosis, we must reckon with their presence as the agents of a complicating infection. The diagnosis and treatment of such infection in sinuses and bronchial tree must be based in part on the same principles as those which apply to any patients with such infections. But in addition they are modified by the important possibility of allergy to the bacteria. Bacterial allergy as encountered in these patients has some important characteristics that differentiate it from the sensitivities to other allergens. It is strain-specific, not species-specific. That is, the patient is sensitive, not to all pneumococci, but to the strain which he himself harbors. Moreover, that sensitivity may take two forms: the usual one is the delayed inflammatory type, comparable to the tuberculin reaction; in rare cases there may be an acute whealing type of reaction. But again this is true for the patient's own strain alone.

These facts have the following practical significance. It is not possible to test for bacterial sensitivity with a stock extract of a species of bacteria. It is not even rewarding to make tests with autogenous killed suspensions of organisms. But the frequent existence of bacterial allergy makes imperative a cautious use of autogenous respiratory vaccines in all patients with respiratory allergy. A rare patient may die in anaphylactic shock from the first dose (I know it to have happened within 5 minutes of the supposed subcutaneous injection of 10,000,000 organisms). A few are precipitated into status asthmaticus with a similar dose. The commonest regrettable event is that a patient is given a few doses of an autogenous vaccine in increasing amounts and he proceeds to get definitely worse after each injection. Both physician and patient then decide that the cure is worse than the disease, and so the vaccine is discarded. Yet in that

vaccine they had the major cause of the patient's trouble and the very key to his successful treatment. What was wrong was the dose. One doesn't begin with large doses of pollen extract in treating hayfever, lest he produce a constitutional reaction; such autogenous vaccines should be given in an initial dose of never more than 5,000,000 organisms, at intervals of not less than a week, and in increments sufficiently small to guard against reactions.

Of particular interest to rhinologists are the structural changes that occur in the nose and sinuses in response to severe prolonged allergic reactions: hyperplastic rhinitis, and its end stage, mucous nasal polyps. Previously attributed to infection, their allergic nature was stressed by Schenck and me[9] in 1933. We were at that time impressed by the very great frequency of such polyps in patients obviously allergic and their absence in non-allergic patients even though they had long-standing extensive infection of various types in sinuses and bronchi. We have felt that bacterial allergy is the commonest factor involved, but that other allergens certainly can and usually do play a part. Indeed, an occasional case is seen in which bacterial allergy may be minimal or even absent, as in a patient whose polyps appear during a severe ragweed hayfever and disappear after frost removes the allergen. The presence of large numbers of eosinophiles in such polypoid and mucosal tissue is a function of the recent exposure to the allergen, not a differentiation from a non-allergic etiology, for as Schenck and I[10] have shown, polyps removed from the same patient a few days apart, first near the end of the ragweed season and again just after frost, showed many eosinophiles in the former and none in the latter. The continued action of allergic factors, we believe, is responsible for the recurrence of polyps after their surgical removal. The logical procedure to prevent such recurrence is therefore adequate attention to the allergic factors involved. This includes a recognition of all participating allergens and their avoidance when possible, or the control of their effects, should they be unavoidable. This, in turn, calls for desensitization with unavoidable inhalants, such as house dust, the drainage, *secundum artem*, of infection where that is necessary, and the use of an autogenous vaccine for bacterial desensitization. In the last connection, I have found it helpful to obtain cultures from polyps and hyperplastic mucosa by grinding the tissue in a mortar with sterile sand. It must be emphasized that this program is of vexing complexity and calls for meticulous care in execution to insure a successful result.

The concept of the allergic cause of polyps has received increasing confirmation and acceptance among rhinologists and allergists. Particularly significant is the effect of those most potent factors in controlling allergic reactions of all sorts, the cortico-steroids, upon polypoid tissue. I shall refer to this later in more detail. Only the pathologists in their textbooks still speak of infection as the only etiology of polyps, and do not even mention allergy—perhaps the penalty of too intent a study of dead rather than living tissue.

While bacteria are under consideration, I wish to refer to an erroneous concept that early gained a foothold and largely still persists in current thinking about the most serious of respiratory allergies, asthma. Chronic respiratory infection and therefore bacterial allergy are frequent in those with perennial respiratory allergic disease. Chronic infection in time causes the ciliated epithelium to be replaced with squamous cells. Especially in the aged do emphysema, mild bronchiectasis and poor circulation accentuate the burden of the disease upon the patient. As a result, asthma in the aged tends to be continuous and chronic, and infection more and more dominates the clinical picture: chronic cough, purulent sputum, low-grade fever, and increase of asthma after every acute cold.

Now it is a well-known fact in all types of clinical allergy that skin reactivity to allergens is greatest in childhood, lessens in adult years, and may often be lost in old age, even though the site of allergic disease, the shock organ, still reacts strongly upon exposure to the allergen. For example, feathers can still cause asthma in a patient whose skin no longer gives a positive test reaction. Therefore skin tests are less and less useful in the diagnostic study of any allergic disease in aging patients.

This poor skin reactivity in the aged, plus the dominance of the clinical picture of their asthma by infection, has been responsible for the erroneous concept that asthma can be classified as either extrinsic, that is, caused by allergens outside the body, or intrinsic, due to causes within the body, notably infection. Indeed, there is a common belief that asthma which begins late in life is practically always intrinsic, infectious and non-allergic. Thus Rackemann[14] has long claimed that extrinsic asthma seldom begins after the age of 45.

This is certainly not true in my experience. Sensitivity to external allergens, if properly and carefully sought for, can be found

in the majority of patients whose asthma begins even in advanced years, and should be suspected in the rest. A further common mistake is to consider the aged patient to be non-allergic because of failure to ask about other evidences of allergy in earlier years. Yet the patient whose asthma began at 70 may have had eczema in infancy, hayfever and hives in adolescence, and typical though mild perennial symptoms of nasal allergy, such as bouts of sneezing or a "wet" nose, for many years, often due to the very same allergens that now affect the bronchi as well as the nose. That infection plays an important role in the asthma of advanced years is freely admitted, but that it is alone responsible except in a small minority of patients is denied.

The role of psychic factors in the production of respiratory symptoms of the types seen in allergic diseases of that tract has had varying emphasis over the years. When this Association was founded, it was the generally accepted view that hayfever was purely a neurosis. Even today most people remember the case cited in the leading text of the late seventies by Beard[1] that told of the patient whose "hayfever" was induced by the sight of an artificial rose. No one paid much attention to Blackley[2] in England and Wyman[17] in this country who in 1873 and 1876 respectively gave convincing proof of grass pollen as the usual cause of hayfever in England and of ragweed in the American late summer variety of the disease. Fifty years later, every one knew that only pollens were responsible. But today, with the increasing recognition of the importance of the psyche as well as the soma in the etiology of all the ills of flesh, the question of the psychic factor in so-called allergic disorders, including those of the respiratory tract, is again being raised. The artificial-rose case has been resurrected, and there are some psychiatrists who are making sweeping claims for the psychic origin of a majority of the diseases under consideration. In presenting specific cases, they point to data on adverse life situations and symptoms, chronologically arranged in parallel columns, showing how the former were promptly followed by the latter. But they ignore such significant dates as the 15th of August when symptoms began; or that, when psychiatric treatment produced such brilliant relief, it had happened when the patient was admitted to a hospital, and so removed from his offending house dust. Even the relapse that came on the day after the patient went home is attributed to his return to an "intolerable situation," meaning his wife, rather than to her allergenic cosmetics.

I do not deny the possible importance of the psychic factors in the production of many and the aggravation of most symptoms of any disease, allergic or otherwise. But I do claim that in the field of allergic disorders they can only pull the trigger, they don't load the gun. I am still looking for an asthmatic patient in whose illness only psychic and no other, including allergic, factors are at work. Moreover, in assessing the relative importance of psychic versus allergic factors in the overwhelming majority of disorders commonly considered allergic, and especially in those of the respiratory tract, I am reminded of the London merchant who was in court on a charge of adulterating his rabbit pies with horse meat. After some damaging evidence had been presented, he admitted that they did contain some horse meat. When further pressed by the judge, he admitted the proportion to be fifty-fifty. "And what is fifty-fifty?" "One horse and one rabbit." I don't deny the presence of a neurotic rabbit in many of these patients, but be sure to find the allergic horse.

Turning now to treatment, the first consideration should always be prophylaxis. In addition to what I have already said on this subject, let me remind you about a preventive measure in respiratory allergy about which all of us could do much more than is being done. Every time a patient with asthma is referred to me, admittedly the most serious of all respiratory allergic diseases, and I get the history of an allergic rhinitis that preceded the asthma by months or even many years, I regret the lost opportunity of preventing the asthma by proper treatment of the rhinitis. Perennial allergic rhinitis is the commonest of respiratory allergies. Even in my practice it is present in 69 per cent of patients whom I see for respiratory allergy.[6] It is the most important respiratory allergy, because it precedes and leads to the asthma in at least 35 per cent of my asthmatic patients. It is the most neglected respiratory allergy. Over half the cases sent to me have existed more than five years, a third for over ten years, and a quarter for over 15 years before an etiologic diagnosis was sought; only six per cent had lasted less than a year. In my practice, many cases of what others have called intrinsic asthma have proved to be the late complication of a long-neglected perennial allergic rhinitis.

The neglect is due in the first place to the patients themselves or to their parents. The symptoms are usually mild, not incapacitating, and persist unchanged over the years. Indeed, some people enjoy their sneezes. Remember the use of snuff by our ancestors.

Children are particularly likely to take their trouble for granted, and their parents, when they realize that the sniffly nose doesn't mean an impending cold, pay little heed. Fully 20 per cent of my cases of allergic rhinitis began in the first decade of life. But general practitioners are also to blame because they fail to inquire routinely about such nasal symptoms in all their patients, or are not impressed by the importance of such symptoms when they do encounter them.

Perennial allergic rhinitis is the worst treated of all respiratory allergies. For years it gets only neglect, or some antihistaminic drugs or a shrinking spray. Finally, when a complicating sinus infection or an obstruction by mucous polyps develops, the mistreatment may continue, now along surgical lines. Not that some operative procedure might not eventually be indicated, but the operations are performed before allergic studies are made and before a two-month trial of allergic treatment is given. Yet such treatment might have resulted in a need for less extensive operative procedures, and occasionally in no operation at all. Above all, proper attention to the nasal allergy might have prevented the far more serious complicating asthma.

From the standpoint of allergy, the first principle of treatment is that complete avoidance of offending allergens will result in complete relief of symptoms. Most patients and doctors now know this, and so they make an effort to take care not only of the patient's bedding, but that of his roommate as well. The commonest current mistake is to believe that a plastic cover over pillows and mattress will completely prevent contact with dust from their contents. There is nothing impervious about a zipper. Such a cover can only reduce the exposure by making the dust take a detour of a few feet in reaching the patient's nose. But what difference do those few feet make to a highly sensitive patient, who, for example, may sneeze and wheeze from the pollen of ragweed plants a few miles away? Plastic covers give partial avoidance, useful while travelling, but not good enough at home. Nor will a spray to coat the fibers of rugs or upholstery produce an effective seal to keep dust particles from leaving them. There can be no compromise in these items: patients must change their bedding to a non-allergic material, preferably foam rubber in pillow and mattress, and the bedroom should be devoid of rugs, upholstery and hangings. Complete avoidance also applies to food allergens. Here, again, patients make two common mistakes: they fail to avoid foods that were not tested (that is why a food test

survey must be sufficiently broad to include the range of what that individual is likely to eat in the course of a year). What is more important, they eat food mixtures of whose ingredients they are ignorant. A basic principle in allergic dieting is this: if you don't know what's in it, don't eat it.

If complete avoidance of an allergen is impossible, then partial avoidance to as great a degree as may be should be the goal. Allergic disease has a quantitative basis: much allergen will cause severe symptoms, less allergen will cause milder symptoms, little allergen may cause few or no symptoms. Partial avoidance alone may be enough to give clinical relief, or when combined with desensitizing procedures, may potentiate such procedures to the point of a satisfactory result. The failure to try for, or to attain a high degree of partial avoidance is an important cause for therapeutic failure. Let me give you two important examples.

Hot-air heating is today the chief cause of failure to control many cases of house dust allergy. We make every effort to render a bedroom allergen-free. But the hot-air heating system, with forced air supply and recirculating ducts, gathers the dust from all the rest of the house, especially from the ground floor with its major supply of heavy rugs and overstuffed furniture (mostly feathers), or from the cellar with its mold spores, and sends it into the bedroom where the patient spends more time than in any other single space. The error is compounded in many instances by using the system to cool the bedroom in the summer. Nor do the filters in use solve the problem: they do not restrain the finest particles, the ones that are the real cause of trouble.

Air-conditioning units are properly recommended to help patients with pollinosis, but they are often improperly used. They rid the air of pollen, not to any degree by means of the rather puny filters which they contain, but chiefly by catching the pollen granules in the water of condensation that forms when the moisture of the air collects on the refrigerating coils. This process is well able to remove the pollen from the air of the room when only room air circulates through the gadget. But it cannot do this for the air of all outdoors. On this one fact has hinged the success or failure of a plan of pollen treatment.

When allergens are unavoidable, and when partial avoidance alone fails to give relief, then desensitization with an extract of the

offending allergens becomes necessary. The results are variable, and never as good as those from complete avoidance, because complete desensitization is never achieved. Nevertheless, the degree of hyposensitization attainable plus the lessened exposure by partial avoidance can give a satisfactory result in most cases, provided we do not make some of the following mistakes. Tolerance is built up gradually; it is therefore unwise to give doses too often or to increase the dosage too fast. Once a week with most antigens and at most twice a week with pollens is the proper interval. Crowding the dosage or the interval will cause constitutional reactions that can be serious and that certainly can make the cure worse than the disease. Nor should patients rush into the office for an injection and then rush out again. The accelerated circulation will help bring on a reaction. The antigens are of protein nature and therefore precipitable by alcohol and various chemicals. Therefore syringe and needle must be sterilized only by boiling or autoclave. The importance of using an autogenous dust extract has already been mentioned.

Symptomatic treatment of allergic disease, useful though it be in giving temporary relief and at times even in saving life, never cured anything. Symptomatic treatment should therefore always be accompanied by definitive and specific measures, when such measures are available. How frequent are the violations of this principle, each one of you knows. I shall only refer to the most common: the careless use of antihistaminics, and the most serious: the improper use of the cortico-steroids.

The antihistaminics are a group of substances, many of them wholly unrelated, which have pharmacological actions that are supposed to be the direct opposite of those of histamine. They were brought into the picture of allergic disease because of the hypothesis that the allergic reaction in body tissue is mediated by the local liberation of histamine. Actually, histamine alone is unable to account for all the local effects in all allergic reactions, and therefore allergists have long thought in terms of H-substances, multiple histamine-like substances, rather than of histamine alone. Moreover, no antihistaminic has exactly the opposite action of histamine. But even with these and other limitations, these drugs are of great practical value, provided we take cognizance of those limitations.

Most antihistaminics have an atropine-like effect in lessening secretion in mucous membranes. In nasal allergy, with its rhinor-

rhea, this is a welcome and desirable effect. But in asthma it is most undesirable, because bronchial secretions are already reduced in amount and more viscid and tenacious in consistency. In the presence of acute infection this is even more the case, and now the further drying effect of antihistaminics can prove disastrous. Many a case of severe asthma has hereby been precipitated into a serious and even fatal *status asthmaticus.*

Antihistaminics in many patients have a more or less marked sedative effect. The first patient in the Mayo Clinic who was given Benadryl® slept for 20 hours, to the considerable discomfiture of the staff. The efficacy of Dramamine® in controlling motion sickness is in large degree a function of this sedative property. A sedative effect is quite desirable when the patient taking the drug is about to go to bed, but it is of serious moment in the daytime when the individual needs to be in full possession of his faculties. A few years ago I incurred the wrath of some manufacturers of these drugs when I[7] pointed out their potential danger in military personnel by impairing the efficiency of the user and so placing him in jeopardy and also those who might be dependant upon his alertness, for example, in piloting a plane or driving a motor vehicle. Here one must bear in mind the frequency with which antihistaminics are self-administered by countless people in seeking relief from the annoyance of the common cold. I am sure that every one of you has knowledge of accidents that were so induced.

Antihistaminics give symptomatic relief from hives. By the same token, they prevent the hives which a diagnostic skin test seeks to elicit. Patients to be tested should therefore be cautioned not to take these drugs on the day when tests are to be made.

Corticotropin and the related adreno-cortico-steroids are the most powerful agents that have come into man's possession since Prometheus stole fire from the gods. But their power can be for evil as well as for good, and we are only beginning to know their possibilities and adapt them to our use. Thus, in infectious diseases they stop the patient's symptoms, that is, his reactions to infection, he looks and feels well for a while, but the bacteria are not affected and the patient dies. Yet this control of symptoms can be turned to life-saving purpose in overwhelming infections, such as meningitis or pneumonia, by staying their progress long enough for the suitable antibiotic to conquer the infective agent.

In allergic diseases these substances have also proved to be by far the most potent means of control of symptoms, almost regardless of their cause or of the shock organ involved. Even chronic lesions, such as nasal mucous polyps, have been caused to disappear. Skin test reactions, both of the acute wheal type and the delayed tuberculin reaction, may lessen and become negative under continued administration. The duration of relief of the symptoms is longer than that from all other medicaments.

Yet the effect of steroids is purely symptomatic; there is no change in the underlying sensitivity. When treatment is stopped, exposure to allergens will again cause symptoms. Polyps recur, and skin reactions resume their former pattern.

What is more important, depending upon dosage and duration of their use, these substances can produce significant and even serious secondary effects that are well known to you, and I have described them elsewhere in detail.[8] But I would like to emphasize the harmful effect of prolonged administration upon the pituitary and the adrenal cortex. Corticotropin given over weeks and months results in partial atrophy of the anterior lobe of the pituitary and marked hypertrophy of the adrenal cortex. But when its use is discontinued, the pituitary picks up only very slowly, while the adrenal cortex atrophies to a size much smaller than it was to begin with. Cortisone, long administered, also results in pituitary atrophy and an even greater adrenal cortical atrophy, and these changes only slowly return to normal after the drug is stopped. In short, for many months after either drug is discontinued, the patient is definitely worse from the standpoint of both pituitary and adrenal size and function than he was when treatment was started.

The use of corticotropin and cortisone in allergic conditions must therefore be formulated with the foregoing facts in mind. The safest indications are those in which short-term (seven to ten days) steroid therapy will relieve the effects of a known antigen that can be avoided in the future. These include: severe drug reactions; contact dermatitis, especially if severe and exfoliating; severe serum sickness; severe ivy poisoning; trichinosis. In this group would also come the preparation of a patient sensitive to Lipiodol® for a necessary bronchogram, or of an asthmatic for an emergency operation. Here also could be listed a few asthmatic patients whose diagnostic studies have been completed, but specific therapy has not yet had time to take hold. This indication should be used cautiously.

Short-term steroid therapy in cases due to unknown allergens is justified in situations that are acute, in themselves of limited duration, but so severe as to threaten life. Severe Loeffler's syndrome would fall in this group. It could also include *status asthmaticus*, but only after all other methods have failed. I have not yet needed to use it in such a case.

Long-term steroid therapy is justified in allergic conditions of unknown cause if they threaten life. Notable examples are periarteritis nodosa, severe allergic purpuras and severe beryllosis.

Long-term steroid therapy is certainly not justified in allergic conditions that in themselves may be annoying but not incapacitating, such as seasonal or perennial rhinitis or urticaria. These can and should be controlled by simpler and safer measures. One doesn't shoot sparrows with 16-inch guns.

The debate now rages as to the justification of long-term steroid therapy in allergic states that can be severe and more or less incapacitating, notably asthma. The opening wedge has been offered by the proponents of steroid therapy who would use it in cases of severe intractable asthma. At first glance this would seem logical. In practice, however, it soon becomes clear that "intractability" is defined very differently by different observers. Men of long experience in allergy find it difficult to recall more than a score or two of really intractable cases over the years. But men of far less experience speak of treating a series of 160 cases of "intractable" asthma. It is clear that these must include patients who certainly have not received proper diagnostic study, and treatment based thereon. As a result, there are being encountered an increasing number of untoward effects of such prolonged therapy in asthmatics: severe gastrointestinal bleeding, osteoporosis and spontaneous fractures, hypertension, vascular disease, psychosis, convulsive seizures and sudden death. It is now know that the minimal amount of cortisone that is required to maintain an asthmatic symptom-free is 50 to 75 mg a day, or more. Even the lowest dose thus represents a functional hypercorticism and is therefore capable of producing in time the more serious manifestations of Cushing's syndrome. I have also seen frank addiction to these drugs. Patients will shop from physician to physician until they find one who is willing to continue to prescribe cortisone for an asthma that should have been treated otherwise, and they become panicky when lowering or cessation of dosage is suggested. Moreover, one must

reckon with transient adrenal insufficiency when treatment is stopped. And, of course, during treatment any attempts at etiologic diagnosis are hampered by the diminished skin reactivity on testing.

It is clear that steroid therapy which may have to be continued indefinitely can lead to serious consequences. It should therefore not be undertaken lightly, or without due regard to its dangers.

In contrast to the many problems raised by the systemic use of steroids, their topical application apparently produces no untoward effects. The amounts involved are small and absorption is negligible. The ophthalmologists have used this method in the conjunctival sac and with good results. An aerosol preparation for inhalation in asthma, on the other hand, has proved of no value. Application of hydrocortisone to nasal polyps by means of a spray has recently been carried out by Silcox[15] with marked reduction in the size of large lesions and disappearance of smaller ones during the continuation of treatment. This should be a valuable adjuvant in the definitive management of this condition.

The treatment of infection is so prominent a part of the daily task of each member of this society that discretion should bid me be silent. But discretion never having been one of my major virtues, I dare to express the thought that in general all too many people are being given all too many chemotherapeutic agents for each and every infection, and so are less and less able to stand on their own immunologic legs. In particular, we are sensitizing all too many allergic individuals unnecessarily to very potent agents given in a trifling illness, so that they are deprived of help in a later serious infection. Penicillin[11] is now the commonest cause of drug allergy, with the most varied and severe reactions, and has replaced foreign sera as the most frequent cause of anaphylactic death. We might prevent much sensitization by not giving penicillin in minor ailments, by avoiding local applications of the drug, by avoiding its depot preparations unless decidedly needed, by giving preference to the oral route of administration, and by avoiding combined parenteral injections with other possible antigens. We could prevent many penicillin reactions in our allergic patients by asking them about previous experiences with the drug, by using oral administration, or if it must be given parenterally, by giving the injection into the arm alone and low enough to permit the use of a tourniquet in case of severe reaction. This thought could

be extended to other of our therapeutic practices with allergic individuals.

I even venture some closing thoughts on surgery in the upper respiratory tract of the allergic patient. It bears repetition that primary and thorough attention to the allergic factors for a two-month period may materially improve the picture and so call for a lesser operative procedure than at first seemed necessary. But those lesions which a clinical and x-ray study now show to remain should be vigorously attacked. The most thorough, seemingly radical operation, such as the Caldwell-Luc for the antrum, will prove in the long run to be the most conservative from the standpoint of the patient's outlook. The golden opportunity to get the best autogenous vaccine is at the time of such an operation. A septum that makes constant lateral contact with the turbinals, or one that obviously interferes with the airway or with the drainage of sinuses, should be straightened. The same is true of a crooked septum which, although not involved in contact or obstruction, offers a considerable surface facing the nostril for the impingement of inhaled particulate matter. Quite as important as the original operation in all of these cases is the regular follow-up and postoperative care by the surgeon *himself*, lest synechiae and other complications arise to nullify the good done by the operation. In the matter of infected lymphoid tissue, one must bear in mind the whole of Waldeyer's ring, not just the faucial tonsils. These are all basic principles that continue to stand as important beacons in the narrow waters of the rhinological sea.

As leaders in your field you know full well that basic principles have been the sure foundation on which were built the great achievements of the past, and, you are the very custodians of such principles. But more than that, you are the teachers of those who will follow and upon whom will rest the responsibility of building the greater glories of the future. You all know how difficult it is to convince the young of the importance of fundamentals. Each new generation insists on making its own mistakes and then hides its confusion behind a false proverb to the effect that "experience is the best teacher." The Spanish version of that saying is more accurate: "experience is a good teacher, but sells its lessons very dearly." And Franklin's Poor Richard was yet more brutally frank: "Experience keeps a dear school, but some will learn in no other, and fools scarcely in that." The wonder is that so many of us have survived and made useful our mistakes; I return to Kipling:

"Then the Gods of the Market tumbled, and their smooth-tongued wizards withdrew,
And the hearts of the meanest were humbled and began to believe it was true
That All is not Gold that Glitters, and Two and Two make Four—
And the Gods of the Copybook Headings limped up to explain it once more."

And so as teachers we try to transmit not only facts, but ideas; not merely data, but principles; so that to knowledge may be added understanding, and out of understanding may grow wisdom.

Broad and Ontario Sts.

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XLIX

VOICE PRODUCTION IN THE LARYNGECTOMIZED PATIENT

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Every laryngologist has often tantalized his inquiring mind with this question: "How can some laryngectomized patients develop highly intelligible postoperative voices while others are unable to speak at all without mechanical aid?" No single answer is readily available.

In reviewing the accomplishments of a small local group of laryngectomized patients, several of whom had been operated upon in other cities, our impressions can be summarized as follows: It appeared that the better educated patients, or those whose financial programs were most demanding, or those whose native ability to imitate was highest, or those whose hearing ability was normal spoke much earlier. On the other hand, those who had sustained a severe hearing loss were unable to hear their own attempts to eructate air. Some surgeons felt that removal of the strap muscles changed the intrinsic mechanics so that voice was developed at a later date; others felt that removal of varying portions of the esophagus had a similar effect; some felt that preoperative or postoperative irradiation, especially the former, had a definite deleterious effect on the patient's ability to speak. In contrast to the clinicians' impressions were those of the esophageal voice teachers, the majority of whom were laryngectomized patients. Certain teachers felt that postoperative laryngectomized voice was entirely esophageal, and others that it was entirely pharyngeal. New patients seeking the help of both types of teachers were immediately confronted with a dilemma. After only partially successful attempts with one teacher they came into the

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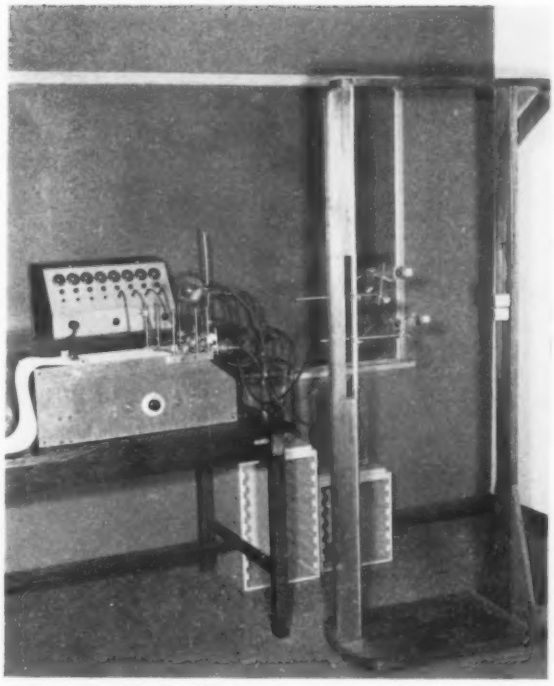

Fig. 1.—Custom built variable speed pentapneumodeik kymograph.

hands of another who assured them they were doing everything wrong. The patient then went home and wrote on paper to his family that he would never speak again.

METHOD OF STUDY

In an attempt to shed light on this problem Dr. Irl H. Blaisdell's enthusiastic interest was imparted to Dr. Walter Amster, of the Hearing and Speech Center at Syracuse University. Dr. Amster chose this problem as his candidate's thesis for his Doctor of Philosophy degree. This was completed in 1953 and dedicated to Dr. Blaisdell. Most apropos at this point, a brief review of his hypotheses, methods and findings are as follows: He proposed that: (1) laryngectomized speakers essentially continue normal breathing and speech co-ordinations, and (2) that speakers judged more intelligible would approximate more closely normal co-ordinations than those judged less intelligible.

Fifteen laryngectomized patients were studied. The necessary data was obtained by using a variable speed kymograph, as shown in Figure 1. With this apparatus tracings of movements of the body wall at the lower sternum and mesogastric areas both during silent breathing and speech were taken. Syllable pulse during speech was also recorded (Fig. 2).

In addition tape recordings of speech were made and submitted to auditing by speech pathology and audiology students for intelligibility ratings (Fig. 3).

In Figure 4 two normal and two laryngectomized patients are recorded during silent breathing. The negative pressure lead presents as a straight line since no syllable pulse is produced without speech. Slightly faster respiration and greater chest expansion per minute are indicated.

Figure 5 represents tracings from two normal speakers and two highly intelligible laryngectomized speakers. Note the increased phrasing necessitated by the last speaker.

In Figure 6 four low intelligibility laryngectomized speakers demonstrate irregular chest wall movements, out of phase movements and dysynchrony.

Those most easily understood approached the speech co-ordination of normal subjects most closely. This co-ordination consisted primarily of rhythm, time and phrasing.

Fig. 2.—Lower sternal lead, negative pressure lead and mesogastric lead in recording positions.

Fig. 3.—Recording speech on magnecord tape recorder.

TABLE 1.

SURGICAL DATA DIVIDED ACCORDING TO INTELLIGIBILITY GROUPS.

	+1 Group N = 8		−1 Group N = 7	
	Yes	No	Yes	No
Deep x-ray therapy previous to or following surgery	0	8	1	6
Radical neck dissection	0	8	2	5
Removal of epiglottis	7	1	6	1
Removal of strap muscles	7	1	5	2
Resection of any portion of esophagus	1	7	1	6
Postoperative fistula	5	3	2	5

Surgical data revealed no direct relationships between the extent of surgery pre- or postoperative irradiation or fistulization with voice intelligibility (Table 1).

It was concluded that there was a definite dissynchrony between respiration and voice production in the poorly intelligible speakers as compared with essentially normal movement of the diaphragm, thoracic cage and voice production in the highly intelligible speakers.

It must be remembered, however, that an individual's potential is difficult to judge on any one single examination and that after subsequent training some of the poorly intelligible speakers are now highly intelligible. The changes we attribute to the difference in technique of voice production which these patients have acquired either by their own efforts or after training with a teacher.

In order to visualize the mechanics a normal speed cinefluoroscopic study was made through the facilities and highly cooperative efforts of the Department of Radiology at Strong Memorial Hospital in Rochester, New York, under the direction of Drs. Ramsey, Watson and Gramiak. Ten laryngectomized patients were studied by giving thin barium and recording the movements of the hypopharyngeal and esophageal walls during voice production as well as by study-

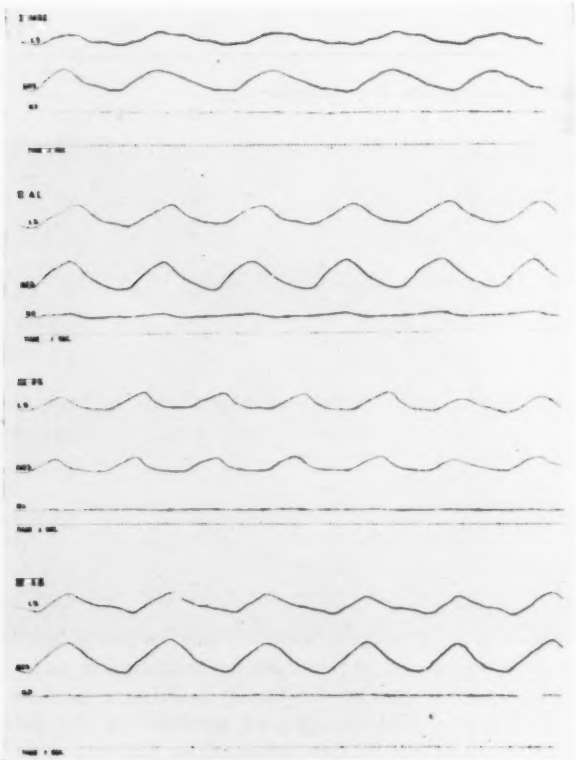

Fig. 4.—L.S., lower sternal lead; Mes., mesogastric lead; N.P., negative pressure lead to record syllable pulse.

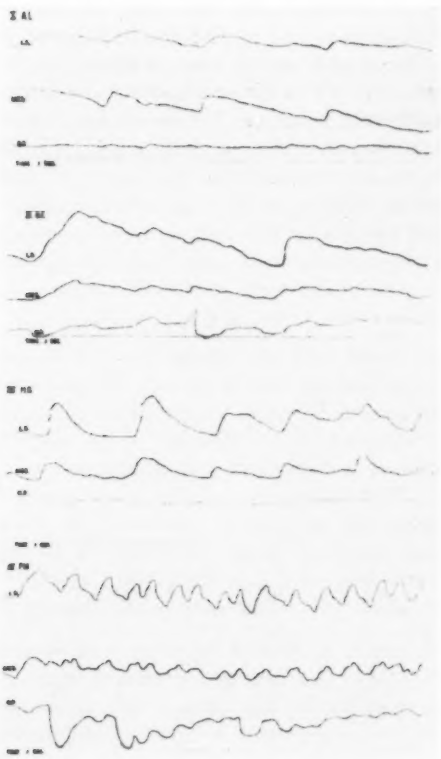

Fig. 5.—L.S., lower sternal lead; Mes., mesogastric lead; N.P., negative pressure lead to recording of syllable pulse.

ing the intercostal and diaphragmatic movements during verbalization of the same material. It soon became evident that the motion at normal speed was too fast for accurate study.

However, the kymographic and taped recordings were submitted to statistical analysis and upheld the findings of the preliminary cine-fluorographic studies which were examined by Dr. Blaisdell and reported as follows: 1) High intelligibility speakers did not appear to employ swallowing behavior. Their intake of air was limited to the proximal portion of the esophagus in the approximate region of the reconstructed crico-pharyngeal sphincter, 2) low intelligibility speakers revealed decided swallowing behavior which propelled air into the medial portion of the esophagus with some escape into the stomach. In these patients the pseudo-glottis appeared to occupy a relatively larger vibrating portion of the esophagus extending below the reconstructed crico-pharyngeal sphincter.

It was proposed that by employing a slow motion technique with a sixteen millimeter Fastax camera set at its slowest speed of 150 frames per second, it would be possible to photograph the fluoroscopic image provided by a television image amplifier so that the intrinsic motion of the pharynx and esophagus could be more carefully studied. This was attempted, but only after a delay of several years necessitated by additional time required for perfection and delivery of the television image amplifier. Test runs recorded no image and it was concluded that the brilliance of the image was still insufficient to allow ultra-slow motion cinefluorography.

However, utilizing normal speed as well as conventional slow motion the last brief section of the motion picture was obtained. They may be identified by the circular mirror image employed, and are silent since sound recorded at slow motion movie speeds cannot be reproduced accurately when played back at normal motion picture film speed.

Repeated fluoroscopic and indirect laryngoscopic examinations of laryngectomized patients led to the impression that the folds of the reconstructed crico-pharyngeus form the only primary vibratory mechanism. The ease with which air escapes past this sphincter determines whether the patient was previously classed as an esophageal or pharyngeal speaker.

These findings appear to support partially the recently reported studies of Dr. Annie Moolenaar-Bijl[1] of the Netherlands who used a

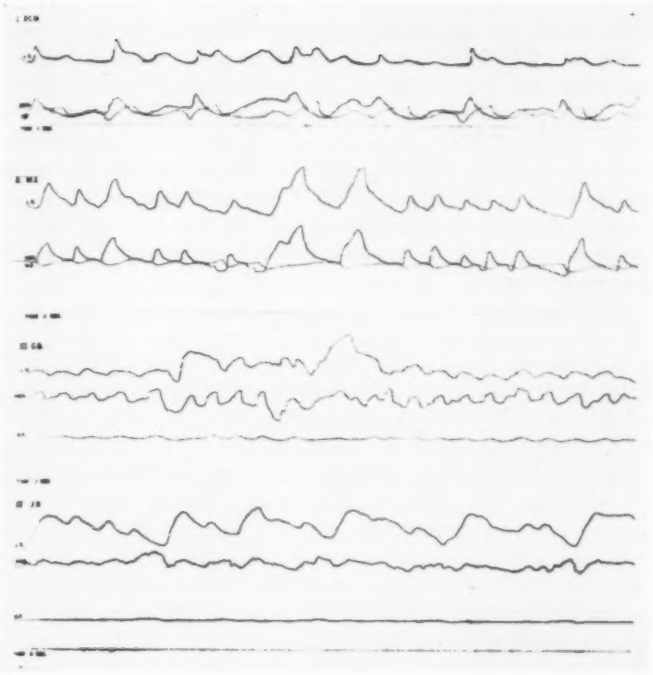

Fig. 6.—L.S., lower sternal lead; Mes., mesogastric lead; N.P., negative pressure lead recording syllable pulse.

single exposure plain film technique in her investigation. She referred to three methods of trapping air—by inhalation, by injection and by deglutition. In our acquaintance those non-laryngectomized teachers of this type of voice have used either inhalation or injection. To inhale and phonate is relatively simple for many. In pronouncing the phrases containing the consonants p, k, and t, "pah" and "mah" the individual's lips or tongue appear to compress air in the mouth and pharynx and allow it to escape into the upper third of the esophagus through the loose folds of the reconstructed crico-pharyngeus muscle, and no audible or visible swallowing takes place. Other syllables, such as "dah," can be produced only after deglutition of air although in many of the highly intelligible speakers the majority of the air stays in the upper third of the esophagus and only small portions of it reach the lower esophagus and stomach. Barium swallow examination postoperatively may be very helpful in evaluating the patient's potential.

CONCLUSIONS

A study of voice production in the laryngectomized patient utilizing kymographic and tape recordings of the phonatory apparatus, when checked by statistical analysis, showed a definite difference in the mechanics by which air was trapped in the pharynx and esophagus by high intelligibility speakers as compared with low intelligibility speakers. Cine-fluorographic studies during phonation, confirmed by repeated fluoroscopic examinations demonstrated that in the patients studied crico-pharyngeal sphincter control was the deciding factor as to where and when the air was trapped. Furthermore, the folds of this sphincter were seen to represent the primary source of sound vibration for voice production. When initial laryngectomy voice training is designed so that the patient can trap air in the upper third of the esophagus without deglutition the highest intelligibility is obtained, though excellent intelligibility can be secured by utilizing the full act of swallowing.

Finally, barium swallow examination should be highly useful postoperatively for evaluation of voice production potential.

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I.

A THIRTY-YEAR REVIEW OF FRONTAL SINUSITIS TREATED BY EXTERNAL OPERATION

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The pioneers of surgery advocated the external drainage of the frontal sinuses. One of the first such operations was what is known today as the trephine operation. This consisted of an external opening and drainage of the frontal sinus without enlarging or opening the nasofrontal duct. A later operation was that advocated by Killian, and this became the most popular operation at the turn of the century. It consisted of a partial removal of the anterior wall of the frontal sinus and a partial removal of the floor, leaving the supra-orbital ridge as a bridge between these two openings. Drainage was established through the anterior ethmoid cells into the nose. This operation failed because the duct frequently closed and because the ridge of bone often sequestrated.

Intranasal Surgery. Because of failures, complications, and disfigurements, these external operations fell into disrepute in the early 1900's. They were followed by intranasal operations. Because of the inherent dangers and indiscriminate use of intranasal operations, there was a return to external surgery. Mosher[13] stated that intranasal ethmoid surgery is not easy and may be dangerous. Fenton[1] stated that the attempt to carry out excessively radical sinus surgery blindly through the narrow nasal pathway is a source of danger. Howarth[7] stated that he thought the pendulum had swung too far to the side of purely intranasal surgery. Patterson[15] stated that, because intranasal procedures had so often proven unsatisfactory and not free from danger, the external operation was again coming into favor.

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In our hospital, intranasal surgery was never widely practiced. The records show that only 15 of the 77 patients under consideration in our series had had intranasal sinus surgery. Thirteen other cases in the chronic allergic group had polypi removed on one or more occasions.

Modern External Surgery. According to Hajek[5] the modern external frontal sinus operation gradually developed from an operation proposed by Jansen, in 1893. It was modified by Howarth,[7] Lynch,[10] Sewall,[17] Ferris Smith,[18] and Negus.[14] In America, this operation is known as the Lynch operation. In Britain, it is known as the Howarth operation. Most of the external frontal sinus surgery done today is some form of these operations, i.e., removal of the floor of the frontal sinus, preservation of the anterior wall, together with the complete removal of the anterior ethmoid cells, and probably the posterior ethmoid cells and sphenoids, together with infected mucosa. In addition, any infection in the antra, or any intranasal obstruction, is promptly treated. This is what we call a complete Howarth-Lynch operation.

Modifications in External Surgery. Goodale,[4] in 1945, reported four cases in which he placed tantalum foil in the nasofrontal duct. In 1948, Harris[6] described the use of a tantalum tube in the nasofrontal duct in three patients in whom the tube was left in position for three weeks. Scharfe,[16] in 1953, also described the use of a tantalum tube in the nasofrontal duct.

Differences of Opinion. As always, in an unsettled problem, one is impressed by the variability amongst the masters about fundamental points. Lynch regarded as dangerous the stripping off of the periosteum from the anterior frontal sinus wall because it may cause periostitis and subsequent osteomyelitis. Furstenberg[2] stated, on the other hand, that the blood supply for the cranial bones comes from the internal periosteum, and that very little harm is done by elevating the periosteum from the anterior wall of the frontal sinus. In a few cases in our series, the periosteum was stripped off the anterior wall of the frontal sinus in order to examine the bone when the x-rays suggested disease. In these cases this procedure was not followed by definite osteitis or osteomyelitis.

Lynch regarded as absolutely essential the stripping away of every shred of mucous membrane from the sinuses, as did Ferris Smith, but Howarth and Negus recommended leaving the mucosa if it is at

all possible, and Negus even suggested skin grafting within the sinus itself, this in addition to skin grafting the nasofrontal duct.

Lynch insisted on removing all of the floor of the frontal sinus, as did Sewall and Ferris Smith. Howarth[9] did at first, and then in 1936, when reviewing his cases, stated that it is not essential to remove all of the outer part of the floor. Negus,[14] in 1947, supported this later idea of Howarth.

Lynch insisted on intranasal treatment of the antra, as did Negus, but Howarth did not stress the importance of this. Lynch, Sewall, and Ferris Smith stressed the importance of including drainage of the sphenoids in the operation; Howarth did not.

Lynch stated that complete removal of the anterior ethmoid cells would provide for an adequate and permanent nasofrontal duct. On the other hand, Ferris Smith, Howarth, and Negus recommended the insertion of a skin graft in the nasofrontal duct, and Sewall advocated the use of a mucosal flap from the middle turbinate to line the nasofrontal duct.

DESCRIPTION OF MATERIAL

This is a survey of the records of cases of frontal sinusitis covering a thirty-year period (1923-1953) in the Royal Victoria Hospital and the Montreal Neurological Institute. The cases considered had inflammatory disease of the frontal sinus. As a rule, there was infection in other nasal accessory sinuses. Excluded were all primary cases of neoplasm, trauma, and mucocele.

Only those cases of frontal sinusitis which had been subjected to external operations were reviewed. During the interval under consideration, the number of acute cases involving the frontal sinuses admitted to hospital was estimated at approximately 425. The number of cases of chronic frontal sinusitis was estimated at approximately the same, bringing the total number of cases to about 850. Other hundreds of patients with less severe frontal sinus infection had been treated on an ambulatory basis. The total number of patients admitted to the Departments of Otolaryngology and Neurosurgery during the period under review exceeded 87,000. We have reviewed the records of about one hundred of these patients who were subjected to external operations, and we have selected 77 in which the records were sufficiently complete and in which the follow-up information permitted the drawing of conclusions. Eleven of the 77

patients could not be located for a recent report, but even in these there was valuable information which justified their retention in the series. The patients were operated upon by the various members of the Departments of Otolaryngology and Neurosurgery.

The indications for external sinus surgery are fairly generally agreed upon.

Negus, in 1947, stressed the importance of the differential diagnosis and elimination of all other causes of headache before resorting to external frontal sinus surgery.

Lynch, in 1924, advocated the prior treatment of antral infection and of intranasal obstruction. This was re-emphasized by Negus. Lynch, in 1929, divided indications for external sinus surgery into two classes: a) the acute manifestations of extension of infection from the sinuses to the orbits and to the brain; b) the chronic cases, those in which the pathology has resisted all other methods of treatment.

In the first class he described the surgery as "emergency" surgery. The surgery of the chronic group he called "last resort" surgery.

Negus stressed as indications for external operations: chronic sinusitis with headache, difficulty in concentration, and depression.

Evidence that the patient is threatened with a serious complication is generally considered as an indication for external frontal sinus surgery.

DIVISION OF MATERIAL

The cases have been classified according to whether the onset of the illness was considered to be acute, acute fulminating, chronic, or chronic in association with gross manifestations of allergic disease (see Table 1 and 2).

We have considered as an "Acute" case a patient who had no history of previous sinus infection and in whom the symptoms requiring external drainage of the frontal sinus began from two weeks to six months before examination. This class of patient usually had a normal or only slightly elevated temperature, and the white blood count was usually below 12,000. Frontal or periorbital swelling was present in five out of the 14 cases. In two cases there were signs of involvement of the central nervous system. Headache and local

tenderness were common symptoms and all had x-ray evidence of frontal sinus disease.

In those patients considered to be "Acute Fulminating," the symptoms and signs reached a climax within one week. There was marked elevation of temperature, 103° to 106° F., and the white blood count rose to 28,000. There was a rapid onset of severe headache and local tenderness. There was external frontal or periorbital swelling in all cases. There were signs of involvement of the central nervous system in 14 out of the 22 patients. There was a history of swimming prior to the onset of the symptoms in at least 50 per cent of the cases. There was definite x-ray evidence of frontal sinus disease in all the cases.

In cases considered to be "Chronic" all patients gave a history of recurring attacks of sinusitis over a period of from one to forty years. On admission there was, as a rule, a normal temperature and white blood count. Signs of central nervous system disease were found in only two out of the 15 cases. Headache and local tenderness were common symptoms. Frontal or periorbital swelling was present in seven cases, occasionally with external fistulae. There was x-ray evidence of frontal sinus disease in practically all cases. The decision to operate was based on the persistence of headache, together with frontal swelling, external fistula or local tenderness, as well as the positive x-ray findings.

In the group of cases listed as "Chronic with Allergy," the signs and symptoms were the same as in the "Chronic" group, except that headache was present in only 50 per cent of the 26 allergic cases, and periorbital swelling and tenderness were unusual. In addition, there were gross manifestations of allergy, such as recurring nasal polypi, persistent asthma, and vasomotor rhinitis, in addition to the sinus infection. In this group the decision to operate was frequently influenced by the severity and persistence of the allergic state.

The cases under review had been treated according to the usual conservative methods of astringent medication, et cetera, with the exception that some of the fulminating cases developed their signs and symptoms so rapidly that surgical intervention had to be undertaken almost immediately. In some of the chronic cases the early treatment included intranasal operations, such as turbinotomy, removal of polypi, intranasal ethmoidectomy, and submucous resection.

TYPES OF EXTERNAL OPERATIONS

Many of the operations in this series were done by different surgeons. It is obviously impossible to say how thorough or how perfect was the technique in each case. It is fair to point out, however, that all of the operators were competent and well-trained. We have estimated that, of the 77 cases, there were 177 external operations performed on the frontal sinuses. With the exception of ablation operations, if both frontal sinuses were operated upon in the same patient these were recorded as two operations. We have restricted the terms "repeat" or "multiple" operations to those cases where the same frontal sinus was operated on more than once.

Howarth-Lynch Operation: A complete Howarth-Lynch operation was performed 58 times. A modification of this operation was performed 53 times.

Trephine: The external trephine operation was performed 37 times. In this operation the frontal sinus was opened externally without enlarging the nasofrontal duct, and by the use of a rubber tube the wound was kept open for several days or until there was evidence that the nasofrontal duct had opened. In nine cases of this series, this was the only operation necessary.

The trephine is especially valuable because it readily establishes the diagnosis when there is doubt, and, at the same time, it provides free drainage of the frontal sinus without any interference with nasal physiology. If it is the only operation required, the external scarring is negligible. If further operation is required, the trephine has been a justifiable preliminary step.

Ablation: Ablation operations on the frontal sinuses, either partial or complete, were carried out on 26 patients. The operation was bilateral in 12 and unilateral in 14. The operation was a partial exenteration of the frontal sinuses in 16 cases, and complete in ten. We have described as a partial ablation operation the removal of the anterior wall, the floor, and mucous membrane of one or both frontal sinuses, together with the ethmoid cells, and this was performed in 13 cases. In three other patients the partial ablation consisted of the removal of the anterior and posterior walls of one frontal sinus. In three cases a partial ablation operation was performed for suspected osteomyelitis, which was not confirmed at operation.

A technique of obliteration of the frontal sinuses, practiced by Doctor W. V. Cone, of the Montreal Neurological Institute, we have

referred to as a complete ablation. In this operation, all that bone which contains the frontal sinuses is removed, together with a complete exenteration of the ethmoid cells, including, if necessary, the entire roof of the orbit, and even the cribriform plate on one or both sides. This operation was performed on ten patients.

Killian: Only three patients of the series had had a classical Killian operation performed. Two of these were not done in our hospital.

Forty-four patients had had a single external frontal sinus operation. The remaining 33 had had multiple external operations. These numbers do not apply to intranasal operations, such as the removal of polypi—one patient had had removal of polypi on 23 occasions.

Of the 44 patients who had but one operation, 21 had had the complete Howarth-Lynch operation (Table 14).

ASSESSMENT OF TREATMENT

When considering the results of surgery on these 77 patients, we have had some difficulty in setting up standards of comparison. Frontal sinusitis may be a serious illness, and in the series under consideration complications occurred in 46 of the cases.

In the uncomplicated case, it is a relatively simple matter to determine whether the patient has been improved by the treatment. One is dealing only with the sinusitis. However, this is an oversimplification because none of these patients have infection confined to one frontal sinus, with all other accessory nasal sinuses remaining normal. In many of these cases there is a bilateral involvement. In trying to assess the value of treatment in a patient suffering from frontal sinusitis, the treatment may have cured the frontal sinusitis, yet the patient may not notice the improvement if one or more of the other sinuses remain infected. This was a difficulty which became very apparent in trying to analyze the answers which we received from our questionnaire.

So far we have considered only the difficulties that arise because there are a number of sinuses. There are even greater difficulties because of the nature of the complications, e.g., a patient who had cerebral venous thrombosis or brain abscess, from which he recovered, may be left with epilepsy. Such a patient might be cured of his initial sinusitis, but he is still suffering from a complication of the sinusitis: recurring seizures.

In the cases considered under the heading, "Chronic with Allergy," the confusion is more marked because of the tendency for nasal polypi to recur, because of the variability of vasomotor rhinitis and because of the persistence of asthma. All of these conditions may frequently be resistant to any known form of treatment.

In trying to determine as accurately as possible the results of treatment of the initial sinus infection, we have listed as improved a patient who died from asthma six years after having had a bilateral modified Howarth-Lynch operation. One year after her operation, the nasofrontal ducts were patent, and subsequent examinations showed the anterior nares to be free from discharge. There was evidence of purulent discharge in the sphenoids. Six years following external operation there had been no gross recurrence of polypi, whereas prior to her external operation she had had six intranasal operations for removal of polypi. To further emphasize the difficulties of arriving at a final assessment, when this patient died of asthma the report of the post-mortem examination mentioned disease in the sphenoids and the ethmoid cells, but the reporter failed to mention anything about the condition of the frontal sinuses.

Another important question that was raised, when assessing the results, is the matter of how long should the symptom-free period be after treatment before one can talk about a cure. Some of the patients in this series have been under observation for over thirty years. One patient had had a Killian operation in 1902, and was well until 1942. Forty years later she had a recurrence of infection in that frontal sinus. The result following the original operation might be called a cure. In 1942 the same frontal sinus was re-opened by the Howarth-Lynch method, and she has had no further trouble for 12 years, again a cure by most standards.

We are impressed with Goodale's statement of 1942: "If the operation has saved a person's life, his health is improved, and he is able to return to his normal life even for a limited period of time, we cannot say that the operation has been a failure or that there has been no improvement." Yet, as Goodale states, "when the frontal sinus again becomes the site of infection requiring re-operation, it is natural to feel that the first operation has failed."

When considering external frontal sinus surgery, Ferris Smith,[18] in 1933, discussed the question of a cure following an external operation on the sinuses. He defined cure as restoration to normal. He

said that such could not always be attained, but it could be approximated. He regarded as a clinical cure the thorough removal of all pathological conditions with a minimal disturbance of function and appearance. He further pointed out that the proper attack on all diseased tissue had been termed radical, and that this is an unfortunate term.

CLASSIFICATION OF RESULTS

The accepted standard of cure, for example, in cancer surgery, is a five-year symptom-free period. Instead of attempting to consider our material on this five-year basis we have grouped our symptom-free patients in five-year periods (Tables 3 and 4). Our conclusions are based on the results of the frontal sinus infection insofar as the case can be assessed, regardless of the results of the more remote complications. We have found it almost impossible to assess the results of treatment of a specific frontal sinusitis without taking into consideration the general state of the nose, as may be found in chronic vasomotor rhinitis or hypertrophic rhinitis. In such patients, when there was a doubt as to the results, the case was listed as improved or not improved (Table 5).

Under "improved" were listed all those cases in which the evidence was not sufficient to justify listing them in the symptom-free class. Yet, in some of these cases there were no definite signs of recurrence or persistence of frontal sinusitis.

Referring to Table 4, it is interesting to note that in this series of 77 patients, 11 have been classed as symptom-free for five years or under, and ten of these were acute or acute fulminating cases. There were 24 patients who have been classed as symptom-free from five to thirty years, including 18 in the acute or acute fulminating group. It might be stressed that of the 41 chronic and chronic allergic patients, only seven were symptom-free, and of these six were in the 5 to 30-year class.

Group One: Acute Frontal Sinusitis. In this group of 14 patients, the majority were under 21 years of age. The symptoms and reasons for external operations have previously been described. Ten of the patients in the group had only one external operation. Two of these were complete ablations. Five of the single operations and the primary operation of three of the multiple operations were trephines. There were four patients with multiple operations. In two

of these the final operation was a partial ablation, and in the other two, modified Howarth-Lynch operations were performed.

Four of the five ablations were performed because of osteomyelitis. In the fifth, the frontal sinus extended beyond the midline. There had been a subperiosteal abscess, and a modified Howarth-Lynch operation had not controlled the symptoms. In addition to the four patients with osteomyelitis, one had meningitis and one had cerebral venous thrombosis. Two of the patients with osteomyelitis had brain abscess. Eleven of the 14 patients in this group were symptom-free from one to 15 years (Table 4). One was improved, and two were not traced.

The predominating organisms in this group were the Staphylococcus and the Streptococcus hemolyticus, each of which occurred in five patients. Other organisms were H. influenzae, Micrococci, and Proteus. In one case, B. Freidlander occurred as a later complication.

All but one of the cases were in the chemotherapy era, and received what we considered to be adequate treatment. This may have been a contributing factor in the results. That it was not the all important factor is shown by comparing the results in this group with those in the chronic allergic group, in which many of the patients had had adequate chemotherapy, but in which the results were generally poor.

Group Two: Acute Fulminating Sinusitis. The majority of the 22 patients in this group were under 14 years of age. Only five of the patients were females. Three-quarters of the patients were operated upon within two weeks of the onset of symptoms. One-third of the cases occurred in the months prior to July, one-third in the months after July, and one-third during the month of July. The infecting organism was the Staphylococcus in 13 out of the 22 cases.

Chemotherapy does not appear to have altered the incidence or the pattern of complications in this type of case (Tables 6 and 7). Chemotherapy has, however, had a beneficial effect upon the results of the treatment of the complications. Complications followed in cases in which treatment had been most prompt and also followed various kinds of operations. Twelve of the patients had single operations. In seven of the ten cases which had multiple operations, the original operation was a trephine. Seven of the final operations were ablations. The results have not favored any one type of operation.

The type and virility of the infecting organisms and the state of the host must be important factors in determining the pattern of the disease. Eight cases occurred before the advent of chemotherapy and 14 after. In 21 of the 22 cases there were serious complications, eleven having had osteomyelitis (Tables 10 and 11) and intracranial complications. Seven other cases had subperiosteal abscess with fistula. In spite of this, 17 of the group are reported as symptom-free. There were only two deaths. Two were not traced.

Group Three: Chronic Frontal Sinusitis. In the chronic group there were 15 patients. The average age was over 25 years. The history of symptoms was present from one to 40 years, with an average of about eight years. Four of the patients had but one external operation. In the other 11 cases, the number of operations ranged from two to seven.

Of the original operations, there were three complete Howarth-Lynch operations, six modified Howarth-Lynch operations, two Killian operations, three trephines, and one partial ablation.

The final operation in five cases was a partial ablation. There was a complete Howarth-Lynch operation in one case and a modified Howarth-Lynch operation in three cases and a complete ablation in two cases.

Osteomyelitis occurred seven times and subperiosteal abscess twice (Tables 10 and 11). Postoperative meningitis occurred in one patient before the advent of chemotherapy. That patient died four days after operation. A second patient with osteomyelitis and a subdural abscess died in spite of adequate chemotherapy. He had had five external operations in the course of about two months prior to his death. The last operation was a complete ablation and preceded his death by only a few days. A third patient, who also had adequate chemotherapy, died about ten days after a complete ablation from osteomyelitis, meningitis, and brain abscess.

In this group there were only three patients classified as symptom-free. This is in marked contrast to the results in the acute and acute fulminating groups (Table 3). There were more complications in this group than in the acute group, but fewer than were present in the acute fulminating group.

We were impressed by the fact that this was an older group of patients in whom the infection had lasted for a long time. Eleven

of the 15 patients had two or more external operations besides intranasal operations.

We have not been able to find a satisfactory explanation for the failure of the first operations in these cases, unless it be that it was due to lack of completeness in the technique. Only in three of the 15 operations was a complete Howarth-Lynch operation done, but one of the 15 was a partial ablation operation, which resulted in the patient being symptom-free.

Of the four patients who each had a single operation, one died from meningitis, as mentioned above. One other case had a complete Howarth-Lynch operation, and has been classified as improved for 15 years. Another had a partial ablation because of osteomyelitis, and has been symptom-free for 17 years. The fourth had a modified Howarth-Lynch operation, and has been improved for nine years.

In this group was one patient, already referred to, who had an original Killian operation. She was symptom-free for forty years before she had a recurrence.

The majority of these patients required several operations, and the results over the years have not been encouraging.

The bacteriology in this group showed more variety than did that of the acute group. In most cases there was a multiplicity of organisms. Staphylococci were present in five cases, Streptococci were present in six cases, pneumococci were present in three cases, H. influenzae in two cases, diphtheroids in three cases, and Micrococci in three cases. In addition to these, there were Proteus, B. coli, and E. coli. In only one case was there no growth, and another was not reported.

There were eight cases in the chemotherapy era, and seven were judged to have had adequate dosage (Table 12). There does not appear to be any obvious correlation between the type of organisms and those conditions which responded favorably to one operation, or between the infecting organisms and the conditions which were ultimately controlled by chemotherapy and multiple operations.

Group Four: Chronic Frontal Sinusitis with Allergy. The average age of the patients in this group was over 25 years. The duration of symptoms, prior to the primary external operation, ranged from one to thirty years, the average being over ten years. Four-

teen of the patients had asthma, 21 had nasal polypi. These conditions were alone or in combination, and several were complicated with vasomotor rhinitis and hay fever. In two patients who have been symptom-free for 17 and 18 years following complete Howarth-Lynch operations, for some unknown reason, in both, the polypi have not recurred, but in one the asthma has persisted.

This has been the most difficult group of all in which to judge results. This may be due to the fact that neither the surgeon, the allergist, nor the patient can adequately distinguish between the results of the sinus treatment on the one hand and the results of the allergic management on the other.

The majority of these patients had been under the constant care of competent allergists, and yet in spite of this, in 15 of the 21 cases traced the allergy had not been arrested. The allergic management consisted of bacteriological studies, the use of vaccines, the elimination of, and desensitization to, known sensitivities.

Many of the sinus operations in this group were carried out with a view to aiding the control of bacterial sensitivities. Bacteriological studies revealed the presence of multiple organisms in most cases, with Staphylococci, Streptococci, and pneumococci predominating. The H. influenzae, Micrococci, Neisseria catarrhalis, and Proteus occurred frequently.

The great majority of the patients had multiple intranasal operations, chiefly for the removal of polypi. We know of only three patients in whom polypi did not return, after external operation, for six, 17, and 18 years. Eighteen of these patients had a single external operation on the frontal sinus. Eight patients had multiple external operations. The repeat operations were performed within a year of the original operation in three cases. In five, the second operation followed the original operation by from five to ten years. Tantalum tubes were inserted in two cases, and in both instances the tube had to be removed after two or three months. Tantalum foil was inserted in three cases. In one it was accidentally removed after two months, and it was necessary to obliterate the sinus. In two other patients the foil remained in position for six years, and though the patients are classed as not improved, the ducts can be probed.

There were three cases of osteomyelitis, three cases of cerebral venous thrombosis. One patient had meningitis in conjunction with

osteomyelitis. Three patients had subperiosteal abscess, one in conjunction with cerebral venous thrombosis. In the patient who had meningitis, the organism was a pneumococcus type 3, and the infection responded to sulphapyridine. There were three cases with cerebral venous thrombosis, of which two were in the prechemotherapy era, and of these one died. The third case, which was in the chemotherapy era, survived four years after the thrombosis. Four patients in this group died. In two, the deaths were directly attributable to asthma. One patient died from intracranial complications. The cause of death in the fourth case was unknown.

Four patients were classified as symptom-free, eight as improved, and eight were regarded as unimproved. Five of the patients could not be traced. For relation to chemotherapy, see Table 13.

Twenty of the 26 primary operations performed in these cases were complete Howarth-Lynch operations. This represents a higher percentage of complete primary operations than were performed in any of the other three groups. In spite of this, and in spite of the fact that only eight of the cases required repeat operations, the results as recorded by us have been less satisfactory in this class of case than in those in the other groups. This may be largely due to the special difficulty of assessment in this group with allergy. We suspect that the actual results of treatment of the frontal sinusitis may be better than our records indicate.

CHEMOTHERAPY

Twenty-eight of the 77 patients in this series were treated prior to 1938. This date was arbitrarily chosen to mark the advent of modern chemotherapy, because sulphanilamide was used in only three patients of the series in 1937, and the largest dose was 45 gr per day for seven days. From 1938 on, the sulphonamides, and later the antibiotics, were used adequately in the presence of serious infections. Due attention was paid to the determination of bacteriology, and as early as possible the choice of drugs was checked with the organism's known sensitivities.

When the 28 cases treated prior to 1938 were compared with the 49 cases treated after 1937, we found that there was no appreciable difference in the incidence of complications between the groups. In sixty per cent of the cases in each period there were complications (Table 7).

The incidence of the acute fulminating cases in the two periods was also practically the same. There were eight cases out of 28 prior to 1938, as compared to 14 cases out of 49 after 1937, representing in each period 28 per cent of the total.

No comparisons can be made in the acute cases. There was only one acute case in this series which occurred prior to 1938, and the patient has not been recently examined.

When the results of treatment of the chronic cases are compared, there is no striking difference in relation to chemotherapy (Tables 6, 10, 11 and 12).

Of the 26 patients in the chronic allergic group, there were 12 prior to 1938, and 14 after 1937. Of the cases that have been traced, about 50 per cent of those occurring in each period have been regarded as improved (Table 13).

In considering chemotherapy in relation to chronic frontal sinusitis with allergy, our analysis has shown that in 21 of the 26 patients, the treatment was carried over into, or was begun in, the chemotherapy era. Five of the patients were not traced. Of the 21 patients in the chemotherapy era, only 14 received adequate chemotherapy. The over-all results in this group have not been encouraging in spite of careful anti-allergic management, radical and fairly thorough surgical treatment, and adequate chemotherapy in the majority of cases.

One might be justified in concluding that the results in this group of cases illustrate what is generally recognized as being true—that sinus infection and allergic manifestations are so intimately connected that their treatment must be considered conjointly, and better results cannot be looked for until there is a more effective anti-allergic treatment available.

IMPORTANCE OF THE NASOFRONTAL DUCT

In spite of the widespread use of the Howarth-Lynch operation and the various modifications that have been suggested, there are still many unimproved cases. Goodale reported 30 per cent and Harris 20 per cent of failures in their respective series of cases. It was because of poor results that Goodale, Harris, and Scharfe each recommended the use of tantalum either as foil or a tube in the nasofrontal duct.

It is rather interesting to note that such men as Lynch, Howarth, Ferris Smith, and Negus have not emphasized or stressed the difficulty

of maintaining the patency of the nasofrontal duct, even though they have described methods designed to maintain an open duct.

We have been impressed with Hajek's statement that attention to adequate patency of the nasofrontal duct once or twice yearly should be considered of more importance than any other factor.

Of the 14 cases in the acute group in this series, information on the present state of the duct was available in six. In two, the primary operation had been a trephine. In one of these the duct was closed at the end of six months, and in the other after four years, and both required reoperation. In one case the duct was closed twelve years after a complete Howarth-Lynch operation. Closure followed in two cases with a modified Howarth-Lynch operation. One, in which a rubber tube had been inserted for two months, was closed three months later and required reoperation. In the other case a porex tube was in the duct for six months, and two weeks after its removal the duct could not be probed. The patient has remained symptom-free for six months.

In another of these patients, following a complete ablation of the sinuses, with the preservation of the middle turbinates, it was not possible to probe the ducts seven years after operation. There was no evidence of recurrence of sinusitis in this case, and the patient has remained symptom-free. This illustrates how difficult it is to establish with certainty the patency of the nasofrontal duct, even in normal individuals, because the duct cannot always be probed.

In the 22 fulminating cases, most of the repeat operations were performed because of complications, and in only two of the group do we have any late information about the state of the duct.

In one case the duct was found to be closed ten years after a complete Howarth-Lynch operation, and required reoperation. In the second case the duct could not be probed eleven years after a modified Howarth-Lynch operation, but the patient was symptom-free and there was no evidence of sinusitis.

Of 15 patients in the chronic group, something about the recent state of the duct was known in six. In three of these there had been repeated operations, because the symptoms persisted. All three patients eventually required an ablation operation, and in one of these even following a most extensive operation, tantalum foil had to be

inserted in the duct at a later date. We have no adequate explanation for the persistence of the infection in these three cases, but there were severe complications in all three.

In one case the duct was known to have remained patent for 12 years after a mucosal flap had been used. In seven cases of the series, a mucosal flap, as described by Sewall, was turned up from the middle turbinate into the frontal sinus. Of these latter cases, in four we have no recent information regarding the state of the ducts. One was a failure and a tantalum tube was inserted later. In the two remaining cases the results were satisfactory.

In another case, nine years after a modified Howarth-Lynch operation, the duct could not be probed, but there was no clinical evidence of infection in the sinuses.

We have information about the recent state of the duct in 11 of the 26 patients in the chronic with allergy group.

In one patient, who had had a mucosal flap placed in one duct in the course of a bilateral complete Howarth-Lynch operation, there was recurrence of infection one year later in the sinus which had not had a mucosal flap. The duct on the side of the mucosal flap was patent. The reinfected sinus was reoperated upon and has remained well for 16 years in spite of the fact that a flap was not inserted at the second operation. The present state of the ducts is unknown.

In another case after a bilateral complete Howarth-Lynch operation, the ducts could be probed three years later, but there was pus present and there was periorbital swelling. Another case required ablation one year following a bilateral complete Howarth-Lynch operation because of osteomyelitis in the presence of closed ducts. Another patient had had a Killian operation in 1936 and required reoperation in 1942—a modified Howarth-Lynch operation. The duct remained open for one year. However, when seen in 1950, the duct was closed, and in 1954 the duct was still closed and there was a fluid level in the sinus. In one patient the ducts were found to be closed and reoperation was necessary 19 years after a trephine operation.

Three patients had had a skin graft in the nasofrontal duct, as advocated by Ferris Smith, Howarth, and Negus. Of these, two are dead, but in one of these, a chronic allergic case, the nasofrontal ducts were known to be open for several years after operation.

Tantalum foil was inserted in the duct in five patients and a tantalum tube was inserted in five other patients of the series. One of the allergic patients had the tantalum foil accidentally removed after three months, and the sinus ultimately had to be collapsed. In two other allergic patients the duct has remained patent in spite of the fact that recurring polypi have been removed. Another patient is well, and a fifth has reported by letter that she is not well. The actual state of the duct is not known. Of the patients with tantalum tubes, five in number, one has not been traced; in two the tubes had to be removed after about two months, because of pain and swelling. The two remaining patients are apparently well, but the actual condition of the ducts is not known.

In two patients with allergy, a lucite rod was inserted, this being retained in position for several months. The patients were taught how to change the rod. In one, a rod was kept in position for six months, and in the other the rod was kept in position for two months. In each of these two cases, two weeks after removal of the rod the nasofrontal duct could not again be probed. One would think that the ducts should have epithelized at least within the period of six months.

In the majority of the patients operated upon in our series, exclusive of those having had the trephine operation, a tube was inserted into the nose from the frontal sinus. In the great majority, this consisted of a hard rubber tube kept in position for about two weeks.

In our experience, the crux of external sinus surgery is the establishment of a patent nasofrontal duct. We have not been convinced that any type of operation, no matter how completely it is performed, can be counted upon to re-establish a patent nasofrontal duct in all cases.

The number of cases in this series in which a mucosal flap was used or in which a skin graft was inserted is not sufficient to allow a true assessment of their values. Tubes, whether rubber, metal, or plastic will not invariably maintain the patency of the duct.

The state of the nasofrontal ducts in this series was definitely known in only 25 of the 77 cases, although many of the other patients are known to be symptom-free or improved. In 16 of the 25 cases, the ducts were considered to be closed at varying lengths of

time after the primary operation, from a few months to forty years. In three other cases the ducts could not be probed, but there were no signs of sinusitis, and the patients are symptom-free.

In only six out of the 77 patients were the ducts known to be open. In two of these, there was tantalum foil in the ducts, and these ducts could be probed after six years in spite of recurring polypi in each case. In one case, skin-grafted ducts remained open for six years. In two cases with mucosal flaps, one was known to remain open for a year and one for 12 years. In the sixth and last case, the ducts could be probed at the end of three years, but pus was present and could be irrigated from the sinuses.

COMPLICATIONS

Under the heading of "complications" we refer to those major conditions which have been directly attributable to the inflammation in the frontal sinuses. In this series of 77 patients, there were 46 with severe complications (Table 7).

In the acute and acute fulminating groups combined, there were 36 patients, 28 of whom had serious complications. All but one of the 22 acute fulminating cases were complicated. Of the 41 chronic and chronic allergic cases, only 18 had serious complications, and ten of these were in the chronic group.

In spite of the fact that 28, or 60 per cent, of the severe complications occurred in the acute and acute fulminating groups, it was in these same groups that we found the highest number of symptom-free patients, 28 cases, or 77 per cent. On the other hand, in the chronic and chronic allergic groups, whereas only 18, or 40 per cent, had serious complications, only six, or 14 per cent, of the cases in these groups were symptom-free. It would appear from this series that, although the great majority of serious complications occur in acute frontal sinusitis, it is in acute frontal sinusitis that one may hope to obtain the best local results. In chronic disease there is not so much likelihood of a severe complication, but there is a much less likelihood of a satisfactory local result from treatment.

OSTEOMYELITIS

The use of the term, osteomyelitis, has given us cause for considerable thought, because we were in doubt as to whether or not we should include under this heading the development of a fistula

Fig. 1.—This 12-year-old girl had acute frontal and maxillary sinusitis. The organism was Streptococcus hemolyticus. The symptoms had persisted for one month prior to admission to hospital in 1931. She had a sub-periosteal abscess and was treated by trephine and intra-nasal antrotomy. One month later she again developed swelling above the eye and required a modified Howarth-Lynch operation.

through the floor of the frontal sinus. We decided to include only those patients who were shown at operation to have an osteomyelitis of the anterior or posterior frontal sinus walls or disease located elsewhere in the skull bones. In addition to these cases of osteomyelitis, there were 11 other cases that did not have osteomyelitis but did have fistulae and subperiosteal abscesses. There was frontal and periorbital swelling in all cases of acute fulminating sinusitis, in eight of the 14 acute cases, in eight of the 15 chronic cases, and in six of the 26 chronic allergic cases (Figs. 1, 2 and 3). We have excluded sub-

Fig. 2.—This 15-year-old girl, classified as a case of acute sinusitis, was admitted to hospital in October, 1947, with a history of bilateral frontal and antral infection for two months. She had severe headache, and had developed swelling over the frontal bone in the midline during the week previous to admission. She had extensive osteomyelitis of the frontal bone, a large sub-periosteal abscess, and a cerebral abscess in the left frontal lobe. She had an ablation operation without removal of the middle turbinates, extensive removal of diseased frontal bone, and drainage of frontal abscess, with adequate chemotherapy. She has since had epileptic seizures, but she is symptom-free as regards the frontal sinusitis and osteomyelitis.

periosteal abscess or fistula if it occurred in a patient who had a previous Killian operation.

There were 25 cases diagnosed as osteomyelitis. Twelve were found to have a subperiosteal abscess at the time of the first operation, and in nine of these there was a fistula leading into the frontal sinus. In three of the 25 cases there were no periorbital abscesses or fistulae, and in ten others we had not sufficient information about the original operations to know whether there were subperiosteal abscesses or fistulae present.

Fig. 3.—This 18-year-old boy was admitted to hospital in 1942, with acute fulminating sinusitis, and his symptoms had persisted for two weeks prior to admission. He had unilateral pansinusitis, peri-orbital abscess, and retrobulbar abscess. He was treated by complete Howarth-Lynch operation, with adequate chemotherapy. This picture was taken a few hours after operation. He remained well for ten years, when he again had swelling about the eye, and had a tantalum tube placed in the naso-frontal duct.

The osteomyelitis was contiguous to the affected frontal sinus in all but one case. In this instance the bone disease was fronto-parietal, and there was a subperiosteal collection of pus in the region of both frontal sinuses at the time of the original operation.

In the 25 cases of osteomyelitis, the Staphylococcus organism was found in pure culture in 14 cases and in combination with other organisms in three cases.

In ten of the cases of osteomyelitis there were no further complications, but in the remaining 15 there were additional complications, mostly intracranial (Table 7).

In assessing the results of treatment in these 25 patients, it was found that 15 were classed as symptom-free. In two patients there has been no recent follow-up. It was rather interesting to find that,

whereas nine cases were treated in the prechemotherapy days and seven were symptom-free, there were 16 treated during the chemotherapy era, and of these only eight were symptom-free.

In reference to these patients being symptom-free, we have assessed the state of the frontal sinuses in addition to the osteomyelitis. As already stated, 15 of the 25 patients had, in addition to the osteomyelitis, intracranial complications, and in the majority of these there were sequelae, such as focal seizures. These have been disregarded in referring to the results.

Of the 25 patients with osteomyelitis, three are dead following intracranial complications. They received what was considered to be adequate chemotherapy, but treatment may have been instituted too late.

Of the 22 remaining cases, in one in which the osteomyelitis was not contiguous to the frontal sinus the infection in the sinus responded to a trephine. Another case, in which the osteomyelitis was limited to the anterior wall of the frontal sinus, responded to a modified Howarth-Lynch operation with partial removal of the anterior wall of the affected sinus. Twenty-three of these patients had ablation operations on the frontal sinuses. Seventeen of these patients had multiple operations. Of the eight patients who each had a single operation, the operation was an ablation in six. Of these eight cases, seven have been symptom-free from two to 17 years, and one has not been traced. The average of these symptom-free periods was over ten years.

Of the 17 patients who had multiple operations, the original operation was a trephine in six cases, a Killian in one, a modified Howarth-Lynch operation in seven cases. Three patients had the complete Howarth-Lynch operation, and in one of these, a chronic allergic case, the osteomyelitis was directly postoperative and was associated with meningitis. In a second case, which was acute and fulminating, the complete Howarth-Lynch operation was carried out too late, since there were already signs of extensive osteomyelitis of the frontal bone. In the third case, also belonging to the chronic allergic group, the osteomyelitis came on about six months after the original operation and the nasofrontal ducts were found to be closed.

Four of the 25 patients with osteomyelitis belonged in the acute group, 11 in the acute fulminating group, seven in the chronic group,

and three in the chronic allergic group. There was a total of 15 cases in the acute and acute fulminating groups, and 13 have remained symptom-free for an average period of 12 years, one was not traced, and one died from overwhelming intracranial infection.

There were ten cases with osteomyelitis in the chronic and chronic allergic groups. One has not been traced and two are dead. The remaining seven cases have been observed for an average period of eight years, and they all have apparently recovered from the osteomyelitis; only two are classed as symptom-free as regards the sinusitis.

All but two of 25 patients with osteomyelitis had ablation operations on the frontal sinuses, together with complete removal of the bone adjacent to the osteomyelitic foci. Fifty per cent of these ablation operations might be described as extreme. This calls to mind the radical treatment of osteomyelitis of the bones of the skull advocated by Mosher, who stressed the importance of early and widespread removal of the bone well beyond the obviously diseased area.

In our analysis of these cases, the osteomyelitis that occurred in association with acute sinusitis did not behave differently from that associated with chronic sinusitis. All the patients who are still alive have recovered from their osteomyelitis. However, in some cases with chronic sinusitis there may be low-grade osteomyelitis, as illustrated by one of our patients who died of brain abscess and meningitis. She was not included in our series as a case of osteomyelitis because there was no description of osteomyelitis having been found at operation. At autopy, a sequestrum was found in the posterior wall of one frontal sinus.

RESULTS

Ablation Operations. There were ten complete ablation opertions carried out for osteomyelitis. In three instances the operation was terminal because the patients were moribund. Six patients are symptom-free and one is improved. The operation had been carried out as a single and a preliminary operation in four cases, in which there was evidence of osteomyelitis and brain abscess in each instance, in addition to the presence of the frontal sinus disease. It followed one or more previous external operations upon the frontal sinuses in six others.

In the 13 remaining cases, a partial ablation of the frontal sinus had been carried out. In two, in which the partial ablation opera-

tion was carried out as the only external operation, there were signs of osteomyelitis when the patients were first seen, and both of these patients have been symptom-free for six and 17 years.

The remaining eleven partial ablation operations followed one or more trephines, modified or complete Howarth-Lynch operations, and six of the patients are symptom-free.

Trephine Operations. In the series under discussion, 22 patients had the trephine operation. The trephine was successful in four acute cases, and in three other acute cases subsequent operations were necessary, in one case because of osteomyelitis. In the fulminating group the trephine was successful in four cases, but in seven other cases subsequent operations were necessary because of such serious complications as osteomyelitis, brain abscess, and cerebral venous thrombosis. In the chronic group, only three trephines were done and all required other operations, in one case for osteomyelitis and meningitis, and in another for subperiosteal abscess.

In the chronic allergic group only one trephine operation was performed, and it was successful in spite of the presence of a subperiosteal abscess and cerebral venous thrombosis.

The trephine operation was successful in nine cases, and failed in 13 other cases chiefly because of associated sinus complications.

The intracranial complications were mostly multiple, with or without osteomyelitis. These complications, for the most part, were treated in the Montreal Neurological Institute. The details of their treatment is beyond the scope of this presentation. The number is probably unusually high because so many such cases are referred to the Montreal Neurological Institute.

Brain Abscess. Brain abscess occurred 11 times. In nine instances it was in association with osteomyelitis, and twice it occurred with meningitis. Four cases occurred in the prechemotherapy era, and of these one died. Seven were in the chemotherapy era, and of these two died. The brain abscess always involved the frontal lobe; it was on the ipsilateral side, and was therefore contiguous.

Cerebral Venous Thrombosis. In nine patients a diagnosis of cerebral venous thrombosis was made. In one, it was in association with brain abscess and osteomyelitis, and was confirmed at postmortem. In most cases it was a presumptive diagnosis, because, in

spite of symptoms and signs of a brain abscess, it was not possible to show the presence of a space-occupying lesion.[19]

Sub-dural Abscess. Sub-dural abscess was found in five patients, always in association with osteomyelitis and sometimes with another intracranial complication. Death was directly attributable to sub-dural abscess in one instance.

Meningitis. Meningitis occurred in six patients. In each instance the organisms were found in the cerebrospinal fluid. In two cases the meningitis was the only complication. In two other cases the meningitis was regarded as an immediate postoperative complication. Of the six cases, two occurred in the prechemotherapy era, and the patients died. Of the four cases which occurred in the chemotherapy era, three survived, including one of the postoperative complications referred to above. This was due to the pneumococcus type 3, and was the first case of type 3 pneumococcal meningitis to recover in this hospital. She was treated with sulphapyridine in 1939.

Of these patients with intracranial complications, the great majority developed sequelae, such as epileptiform seizures.

IMPRESSIONS

It is difficult to draw conclusions from a small series of cases, but we have formed certain impressions from this study.

Complications were more frequent in the acute cases of frontal sinusitis, but the greatest amount of local recovery occurred in these cases. Conversely, complications were less common in chronic frontal sinusitis, but satisfactory improvement in the local condition occurred less frequently. We are of the opinion that in the chronic allergic group the prevalence of poor results was due largely to the fact that the allergy had not been controlled in spite of adequate management.

We have been unable to demonstrate any striking difference in the incidence or type of complication in frontal sinusitis in relation to chemotherapy, nor have we noted any striking difference in the results of treatment either of acute or chronic sinusitis before and after the advent of chemotherapy, except in the treatment of meningitis.

We believe that the judicious use of adequate chemotherapy has been a more valuable adjunct to surgery in the treatment of acute and chronic sinusitis than the above finding would appear to indicate.

In this study it was found that the more complete the initial operation, the less likelihood was there of repeated operations on the frontal sinus.

Twenty-three of twenty-five cases of frontal sinusitis with osteomyelitis required an ablation operation on the frontal sinuses.

In this series of cases of frontal sinusitis the osteomyelitis was associated with serious intracranial complications in 50 per cent.

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TABLE 1.
DIVISION OF CASES WITH REFERENCE TO TIME SINCE LAST EXTERNAL OPERATION.

PERIOD OF TIME	ACUTE	ACUTE FULMINATING	CHRONIC	CHRONIC WITH ALLERGY
Under 1 year	2	1	1	0
1 - 5 years	5	4	4	4
6 - 10 years	3	3	2	4
11 - 20 years	2	7	2	8
21 - 30 years	0	3	0	1
Untraced	2	2	2	5
Dead	0	2	4*	4**

*1 death was due to cardio-vascular disease after 15 years of improvement.
**2 deaths resulted from asthma six and seven years after operation, one improved and one not improved.
1 death of unknown causes four years after improvement.

TABLE 2.
DIVISION OF CASES WITH REFERENCE TO THE TIME FROM THE ONSET OF FIRST SYMPTOMS TO THE END OF OBSERVATION.

PERIOD OF TIME	ACUTE	ACUTE FULMINATING	CHRONIC	CHRONIC WITH ALLERGY
Under 1 year	0	0	0	0
1 - 5 years	6	5	2	1
6 - 10 years	5	3	4	1
11 - 20 years	2	8	0	7
21 - 30 years	0	4	1	4
Over 30 years	0	0	2	5
Not traced	1	0	2	4
Deaths	0	2	4	4

TABLE 3.
SUMMARY OF RESULTS.

GROUP	ACUTE	ACUTE FULMINATING	CHRONIC	CHRONIC WITH ALLERGY	TOTAL
Symptom-free	11	17	3	4	35
Improved	1	0	3	7	11
Not improved	0	1	3	6	10
Not traced	2	2	2	5	11
Dead	0	2	4*	4**	10

*One death from cardio-vascular disease after 15 years of improvement.

**Two deaths from asthma. One improved six years, one not improved seven years.

One death of unknown cause: improved four years.

TABLE 4.
DIVISION OF SYMPTOM-FREE CASES WITH REFERENCE TO TIME SINCE LAST EXTERNAL OPERATION.

PERIOD OF TIME	ACUTE	ACUTE FULMINATING	CHRONIC	CHRONIC WITH ALLERGY
Under 1 year	2	1	1	0
1 - 5 years	4	3	0	0
6 - 10 years	3	3	0	1
11 - 20 years	2	7	2	2
21 - 30 years	0	3	0	1
TOTALS	11	17	3	4

TABLE 5.
DIVISION OF IMPROVED CASES WITH REFERENCE TO TIME SINCE LAST EXTERNAL OPERATION.

PERIOD OF TIME	ACUTE	ACUTE FULMINATING	CHRONIC	CHRONIC WITH ALLERGY
Under 1 year	0	0	1	0
1 - 5 years	1	1	1	2*
6 - 10 years	..	..	1	1**
11 - 20 years	..	..	1†	4
TOTALS	1	1	4	7

*One died, cause unknown.

**Died from asthma.

†Died of natural causes.

TABLE 6.
DIVISION OF CASES AND RESULTS OF TREATMENT IN RELATION TO THE ADVENT OF CHEMOTHERAPY.

CASES PRIOR TO 1938				CASES AFTER 1937		
SYMPTOM-FREE AND IMPROVED	DIED	NO. OF CASES	GROUP	NO. OF CASES	DIED	SYMPTOM-FREE AND IMPROVED
..	..	1	Acute	13	..	12
6	1	8	Acute fulminating	14	1	11
4	1	7	Chronic	8	2	3
5	1	12	Chronic with Allergy	14	..	7
15	3	28	Totals	49	3	33

Four deaths not attributed to frontal sinusitis are omitted from this table.

TABLE 7.

COMPLICATIONS OCCURRING IN FORTY-SIX OUT OF SEVENTY-SEVEN PATIENTS.

PRIOR TO 1938

Total Cases: 28

Complicated Cases: 17

COMPLICATION	NUMBER OF CASES	SYMPTOM-FREE	IMPROVED	NOT IMPROVED	NOT TRACED	DIED
Osteomyelitis	5	3	0	1	1	0
Osteomyelitis with Brain Abscess	3	3	0	0	0	0
Osteomyelitis with Cerebral Venous Thrombosis	1	1	0	0	0	0
Meningitis with Brain Abscess	1	0	0	0	0	1
Meningitis	1	0	0	0	0	1
Cerebral Venous Thrombosis	* 3	2	0	0	0	1
Fistula with Sub-periosteal Abscess	3	0	1	0	2	0
	17	9	1	1	3	3

After 1937

Total Cases: 49

Complicated Cases: 29

COMPLICATION	NUMBER OF CASES	SYMPTOM-FREE	IMPROVED	NOT IMPROVED	NOT TRACED	DIED
Osteomyelitis	5	2	1	1	1	0
Osteomyelitis with Brain Abscess	3	3	0	0	0	0
Osteomyelitis with Brain Abscess and Sub-dural Abscess	1	1	0	0	0	0
Osteomyelitis with Brain Abscess, Meningitis and Sub-dural Abscess	1	0	0	0	0	1
Osteomyelitis with Brain Abscess, Cerebral Venous Thrombosis, and Sub-dural Abscess	1	0	0	0	0	1
Osteomyelitis with Sub-dural Abscess	2	1	0	0	0	1
Osteomyelitis with Meningitis	2	0	1	1	0	0
Osteomyelitis with Cerebral Venous Thrombosis	** 1	1	0	0	0	0
Brain Abscess	1	1	0	0	0	0
Meningitis	1	1	0	0	0	0
Cerebral Venous Thrombosis	3	2	1	0	0	0
Fistula with Sub-periosteal Abscess	† 8	4	1	1	2	0
	29	16	4	3	3	3

*Fistula with Peri-orbital abscess in two cases.

**Ipsilateral optic atrophy.

†Retrobulbar abscess in one case symptom-free for 10 years.

TABLE 8.
DIVISION OF CASES. SUB-PERIOSTEAL ABSCESS WITH FISTULA. NOT INCLUDING CASES WITH OSTEOMYELITIS.

CASES PRIOR TO 1938	GROUP	CASES AFTER 1937
0	Acute	1
2	Acute fulminating	5
1	Chronic	1
2	Chronic with Allergy	1
5	Total	8

TABLE 9.
ANALYSIS OF DEATHS IN RELATION TO THE ADVENT OF CHEMOTHERAPY AND TO THE IMMEDIATE CAUSES.

PRIOR TO 1938

CAUSE	NUMBER OF CASES
Meningitis	1
Meningitis and Brain Abscess	1
Cerebral Venous Thrombosis	1
TOTAL	3

AFTER 1937

CAUSE	NUMBER OF CASES
Osteomyelitis, Brain Abscess, and Meningitis	1
Osteomyelitis, Brain Abscess, and Cerebral Venous Thrombosis	1
Osteomyelitis, and Sub-dural Abscess	1
TOTAL	3

DEATHS NOT ATTRIBUTABLE TO FRONTAL SINUSITIS OR ITS COMPLICATIONS

CAUSE	NUMBER OF CASES
Asthma	2
Cardiovascular Disease	1
Cause unknown	1
TOTAL	4

TABLE 10.
FRONTAL SINUSITIS WITH OSTEOMYELITIS. RESULTS OF TREATMENT WITH REFERENCE TO GROUPS.

PRIOR TO 1938
Total of 28 Patients

GROUP	ACUTE	ACUTE FULMINATING	CHRONIC	CHRONIC WITH ALLERGY	TOTAL
Symptom-free	0	5	1	1	7
Improved	--	--	--	--	--
Not improved	--	--	1	--	1
Not traced	--	--	1	--	1
Dead	0	0	0	0	0

TABLE 11.
FRONTAL SINUSITIS WITH OSTEOMYELITIS. RESULTS OF TREATMENT WITH REFERENCE TO GROUPS.

AFTER 1937
Total of 49 Patients

GROUP	ACUTE	ACUTE FULMINATING	CHRONIC	CHRONIC WITH ALLERGY	TOTAL
Symptom-free	3	5	0	0	8
Improved	--	--	1	1	2
Not improved	--	--	1	1	2
Not traced	1	--	--	--	1
Dead	0	1	2	0	3

TABLE 12.
RESULTS OF TREATMENT IN CHRONIC FRONTAL SINUSITIS WITH REFERENCE TO CHEMOTHERAPY.

CASES PRIOR TO 1938		CASES AFTER 1937
1	Symptom-free	1
2	Improved	3
2	Not improved	1
1	Not traced	1
1	Died	2
7	Totals	8

TABLE 13.
RESULTS OF TREATMENT IN CHRONIC FRONTAL SINUSITIS WITH ALLERGY IN REFERENCE TO CHEMOTHERAPY.

CASES PRIOR TO 1938		CASES AFTER 1937
3	Symptom-free	0
2*	Improved	7**
3†	Not improved	5
3	Not traced	2
1	Died	0
12	Totals	14

*One death from asthma.

**One death due to unknown causes.

†One death from asthma.

TABLE 14.
SUMMARY OF OPERATIONS.
MULTIPLE OPERATIONS ON THIRTY-THREE PATIENTS.
SINGLE OPERATIONS ON FORTY-FOUR PATIENTS.

TYPE OF OPERATION	NUMBER OF TIMES PERFORMED	NUMBER OF PATIENTS WHO HAD THE FRONTAL SINUS OPERATED UPON ONCE
Complete Howarth-Lynch	58	21
Incomplete Howarth-Lynch	53	8
Trephine	37	9
Partial Ablation	16	2
Complete Ablation	10	4
Killian	3	—
	177	44

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SOME OF THE INDICATIONS AND CONTRAINDICATIONS FOR HORMONAL THERAPY

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This discussion will be limited to ACTH, cortisone, estrone, testosterone, some of the indications and most of the contraindications.

The reasons for presenting this subject are as follows: 1) To review some of the indications for the use of hormones in the treatment of certain specific diseases; 2) to sound ample warnings about possible serious sequelae, if contraindications are not thoroughly understood and observed, and 3) to strongly emphasize what the writer believes to be a fact, namely, that hormonal deficiencies and imbalances are, as a rule, multiple and only one part of a general deficiency. Nutritional and electrolyte deficiencies and imbalances must be considered concurrently.

The latter will be stressed throughout this report as it seems to be the least understood, and certainly accounts for many therapeutic failures in the use of hormones. While adequate documentation is admittantly lacking, the writer has a large amount of clinical evidence pointing to its factuality. It is interesting to note that McCarrison[1] made some pertinant observations based on well controlled animal experiments as follows: "My studies have provided some interesting contrasts in the behavior of certain endocrine organs in the presence of food faults. Thus, the adrenal glands tend to undergo enlargement while the thyroid tends to atrophy in the presence of food deficiencies. When, on the other hand, the food is excessively rich in proteins and fats without any deficiency of vitamins, the thyroid tends to enlarge and the adrenals to diminish in size. In the former case the body appears to need more adrenal and less thyroid hormone; in the latter, more thyroid and less adrenal hormone. The combination of effects produced in the thyroid and

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adrenal glands in the presence of food deficiency is paralleled by the the observation of Herring[2] that in rats fed on thyroid extract the adrenals almost double their weight, while their epinephrine-content is also increased; and by his more recent observation that the adrenals increase and the thyroid diminishes in size in consequence of pregnancy. The pituitary enlargement—occurring as it does in the organ resulting from thyroidectomy and from castration, the similarity being carried further when the thyroid and testicular atrophy resulting from avitaminosis are remembered.

"It seems, therefore, that both the functional perfection and the correlations of the endocrine organs are dependent upon a properly balanced and vitamin-containing food supply; dietetic deficiency means endocrine insufficiency."

Until we have conclusive evidence to the contrary McCarrison's well documentated and controlled animal studies of the behaviour of certain endocrine glands in the presence of various nutritional deficiencies should be accepted. There is a vast amount of clinical observations which confirms his experiments. He emphasizes throughout his book the crucial importance of balance in the endocrine secretions and balance of the vitamin-containing foods. He omitted discussion of the electrolytes, probably because so little was known at that time. Much knowledge is still lacking today.

It is of practical interest to note that in rats fed on thyroid extract the adrenals almost doubled in size with an increase in epinephrine content. It is not unusual to have patients report that they have been advised to take thyroid extract the remainder of their lives because of a low basal metabolic rate, without giving a thought to other means of promoting a more normal physiological activity of the thyroid. This and the misuse and abuse of the female hormones have not added to the prestige of our profession. The latter has at times been used almost to the point of brutality! It should be obvious to all that an imbalance is created which will produce a dysfunction throughout the entire delicate mechanism of the whole endocrine system.

The toxic effects of the imbalances have not been adequately stressed. There was a report recently published by Grant and Leopold[3] which seems to emphasize the dangers of large doses of cortisone (100 to 300 mg daily for three years) without the concurrent administration of potassium chloride and the sex steroids.

This young woman, 33 years of age with a severe rheumatoid arthritis, developed a Guillian-Barre syndrome with paralysis of both legs and the left facial nerve. Her face was moon-shaped.

The authors postulate that the Guillian-Barre syndrome was caused by an infection starting in the gastro-intestinal tract and involving the central nervous system. They further postulate that the cortisone may have had nothing to do with the syndrome, or perhaps it helped its development by breaking down the usual barriers of resistance. The writer respectfully suggests that neither postulation may be entirely correct. No one has demonstrated that the Guillian-Barre syndrome has an infectious genesis.

It seems quite likely that the cortisone given in such large doses over such a long period of time did have some direct effect by seriously disturbing the endocrine balance and the whole electrolyte system. It would have been interesting to know how this patient would have reacted had the following regime been carried out: 1) Adequate doses of potassium chloride and other electrolytes during the entire course of cortisone therapy with sodium restriction; 2) mixed sex steroids; 3) vitamin supplementation and, 4) adequate nutritional regime.

Kinsell and Partridge[4] summarize the present stage of hormonal therapy as follows: "The accumulation of knowledge and the development of concepts regarding the place of ACTH and cortisone in clinical medicine have followed an interesting pattern during the past two years. The first period might be termed the *phase of incredulity*. This persisted a relatively short time. The second phase would be dubbed properly the *era of extreme euphoria*. The third period is now with us. Its most outstanding characteristic is the *alarm reaction*."

Perhaps the word "alarm" should be changed to "caution." There is no doubt that hormones have great possibilities of producing dangerous sequela if the indications and contraindications are not thoroughly understood and obeyed. Until such time as we have a chemical or biological assay that will determine accurately a deficiency, or imbalance, we must proceed carefully along accepted, conservative routes and detour at great risks to our own reputation and to our patients' well being. One must be always alert to obvious changes in electrolyte metabolism, due to salt and water retention. This is easily detected by weight gain and tissue edema. Hormones

have such great potentialities for good that their cautious use should no longer be delayed. It is of vital importance to correct all other deficiencies and imbalances, thereby giving the endocrine glands a healthy and congenial chemical environment in which to function and to produce their own hormones by normal synthesis. The exception to this rule is when these glands have been destroyed by surgery, radiation or disease.

INDICATIONS FOR HORMONAL THERAPY IN OTOLARYNGOLOGY

Asthma that is refractory to conventional treatment, usually of the intrinsic variety. ACTH or cortisone is indicated. Results are excellent in selected cases. Keep the dosage low and reduce it some each day. Short courses of treatment as often as required are desirable and safe. The addition of sex steroids in older persons is nearly always indicated for hormonal balance.

Hay Fever. If the patient has not had or fails to respond to desensitization or antihistaminic therapy, ACTH or cortisone is indicated with helpful results. There are short, sometimes long, periods of relief.

Perennial Allergy. In older persons conventional therapy frequently fails. Cortisone combined with the sex steroids is usually quite rewarding. Again small dosages should be given over short periods of time to determine the continuing need.

Drug Sensitivities. In drug sensitivities, such as contact dermatitis, ACTH or cortisone and neo-cortef shauld be used locally. The results are good.

Tension States. Vascular headaches respond to sex steroids, Estrone and testosterine, cortisone 12½ mg twice daily. The results are very good in selected cases. One should discontinue medication frequently as a control to determine its need.

Idiopathic Granuloma. Here, ACTH or cortisone may be lifesaving at times.

Hemorrhages. In nasal, orbital and bronchial hemorrhages or in those of unknown origin, probably vicarious menstruation due to a disturbance in the sex steroid levels, especially imbalances, sex steroids and cortisone are indicated.

Degenerative Diseases. In acoustic, ocular and other dysfunctions, occurring in the aging patient, sex steroids plus the conco-

mitant administration of ACTH or cortisone are indicated. Results are doubtful and still in the experimental stage but certainly worthy of further clinical trial before final evaluation.

CONTRAINDICATIONS FOR HORMONAL THERAPY

One should remember that the past is a learned prologue of the future. Until time tested, all new therapeutic measures may be quite beguiling, and at times illusory. Until complete information is available regarding the physiological effects, the mechanism of their action, the indications for, and the possible serious sequelae of the steroids, the following should be considered, for the time being at least, as contraindications: Malignant hypertension, congestive heart failure, severe diabetes, chronic glomerulonephritis, Cushing's syndrome, psychoses and psychopathic personalities, hirsutism, peptic ulcer, tuberculosis, active or recently healed. Certain experimental work has suggested that estrogens are carcinogenic when administered to animals which have inherited sensitivity to breast cancer. Great caution should be observed in women who give a familial history of carcinoma and the steroids are absolutely contraindicated if there is a personal history of breast or genital carcinoma.

This warning in no way applies to testosterone, the other sex steroid, which is so frequently indicated in women for tensions and hemorrhages. There is some accumulated evidence strongly suggesting that testosterone, the antimetabolite of estrone, may be a valuable therapeutic agent in the management of carcinoma of the female genital tract.

Much basic research must yet be done before the diagnosis of any hormonal deficiency can be put on a scientific status.

At the time of this writing the estimation of steroid blood levels is still a research problem. It will probably remain on a research basis for some time as the technique for accurate determination of these blood levels is a very delicate, and so far an unstandardized procedure.

The presumptive diagnosis of sex steroid deficiencies seems to be more within the range of our present clinical knowledge; at least it is more easily assumed than any other hormonal deficiency.

Women have told us from time immemorial that their tensions, migraine headaches, their nervousness, their allergies, even their asth-

matic bouts, have at times disappeared completely during pregnancy, only to return post partum. We have never given these voluntary statements the diligent attention that was warranted by the physiologic facts observed by these patients. In addition, it was observed that there were many more intractable allergic patients among women than men. Therefore, it seemed obvious that in women the body was supplied with something during pregnancy, perhaps a better balance, that did not exist in the non-pregnant woman or in the male.

Until better diagnostic methods are developed one must rely to a great extent on a detailed gynecological history, which is not without merit and the subcutaneous injection of a therapeutic dose of the steroid which is often quite helpful. It must be remembered that a positive diagnosis of a steroid deficiency cannot be made by laboratory or other objective methods.

The following questions should be answered by the patient if the physician is to be assisted in making a presumptive diagnosis of a sex steroid deficiency or imbalance: 1) Beginning with the menarche, did the patient exhibit any abnormalities such as menalgia menorrhagia or amenorrhea? The last is especially important if it occurs in the obese young female or in the post partum period. 2) What was the condition of health during pregnancy? Did migrainous and other types of vascular headaches disappear or become less severe? 3) Did allergic conditions such as hay fever, asthma and perennial allergies improve or disappear entirely?

The injection of a therapeutic dose of either estrogen or androgen is a simple and practical test but it is in no way a completely reliable method of determining a steroid deficiency. It is suggestive and should be used. The patient must report the clinical response within 24 to 48 hours. If the patient observes a definite improvement in tension and other symptoms, the test must be considered as strongly suggestive of a deficiency or "slightly positive." It is frequently noted that the patient will report such a marked relaxation from tension that he will describe the reaction as one of complete exhaustion. This is more apt to happen when one of the androgens are being given, either to the male or female.

If there is no change at all, as frequently happens, the test should be recorded as negative. If the tension or other symptoms are made worse it is indicative of an over-supply already in the body of the

steroid being tested. Do not give the patient this steroid, but consider the opposite sex steroid. Estrogens and androgens are antimetabolic. The gynecological history as outlined above has a much more conventional connotation than the therapeutic injection as it is not influenced so much by the emotions of the patient.

PRINCIPLES OF HORMONAL THERAPY

Before any specific therapy is suggested certain fundamental principles must be recognized. For example, the adult male produces a small amount of estrogenic substance which largely comes from the adrenal cortex, perhaps a small amount even from the testicle. The adult female produces significant amounts of androgen in the adrenal cortex. In the treatment of many conditions in both men and women several authors have suggested a ratio of 20 to 1 testosterone and estron. This ratio has not as yet been finally determined. There is great individual variation which must be carefully considered. It is therefore incorrect to speak of separate male and female hormones. No normal woman is without masculine secretion; no man is without female secretion. Someone has remarked "No Adam without an Eve."

Many investigators have postulated that the androgens probably have a direct effect on the pituitary gland by stimulation, which may in turn increase ovarian activity in the same manner. Antimetabolitic activity or neutralization between estrone and testosterone due to chemical structural resemblance has been espoused by Woolley[5] but this theory has not met with favor among endocrinologists.

There is already impressive clinical evidence to indicate that the concomitant administration of the sex steroids with cortisone may avoid some of the adrenal changes and negative nitrogen balance associated with the use of cortisone alone. This evidence strengthens the writer's postulation that if there is any endocrine deficiency it is nearly always multiple and is accompanied by nutritional and electrolytic deficiencies and imbalances. Vitamin C and the whole B complex given intravenously greatly enhance the therapeutic effect of all hormonal therapy, because they supplement other deficiencies.

Of course, an adequate nutritional regime is vital to the patient's welfare. Oral vitamin and mineral supplementation must be continued during the critical periods. The suggested therapy for a few

specific diseases to follow is, of course, crudely unfledged. Until we are better informed on the physiological effects of the hormones and the mechanism of their actions each physician must exercise profound and discriminating judgment in the selection of a relatively new and mostly untried therapeutic agent. Not all diseases listed as indications for possible hormonal therapy will be discussed.

We have accepted certain acoustic dysfunctions as a necessary part of aging. Nothing has developed so far to refute that time-honored conviction, perhaps nothing will. However, the widespread recognition of the interrelationships existing between steroids and metabolic processes emphasizes the importance of a possible endocrine approach to the problem of aging and it is hoped in the future to delay some of the degenerative changes which usually follow. Goldzieher and Goldzieher[6] point out that the loss of ovarian or testicular hormones in the aged withdraws one of the most important metabolic regulators of the organism. In support of this statement, attention is directed to the protein-building properties of both estrogen and androgen, their combined effects on calcium metabolism and the mineral content of the skeletal system. Even the central nervous system, these authors state, is under the influence of the gonadal hormones and strongly reacts to their absence.

This would again seem to support the writer's hypothesis that acoustic dysfunctions, as well as all the cranial and even the autonomic nervous system, probably react adversely when there is a deficiency in these important hormonal metabolic regulators.

Ample clinical evidence to support this hypothesis is not immediately available. Clinical investigations are going forward. Masters[7] points out that this has been deduced from the fact that up until the age of menopause the female has much less atherosclerosis than the male, and lower concentration of SF 10-20 molecules. However, the incidence of atherosclerosis increases as estrogen production diminishes, and when the female reaches the age of about 60, it is approximately the same as the male. Masters further states that, on this basis, it would appear desirable to administer estrogen in small doses to most postmenopausal women.

Extending the concept of metabolic interdependence, some workers, (Goldzieher and Goldzieher[6]) feel that steroid therapy cannot exert its optimum effect unless the nutritional requirements are adequately maintained. Vitamins are necessary for the elaboration

of basic enzyme systems, and the B vitamins as a group affect the intrinsic metabolism of all tissues. Furthermore, in line with the current trend, which increasingly emphasizes the concept of interrelationship in human metabolism, Goldzieher and Goldzieher point out that vitamin supplementation in the aging patient is not only important from a nutritional standpoint but also necessary to increase the effectiveness of steroid therapy. It is believed by some that the steroid hormones may influence enzyme concentration, may be component parts of an enzyme system or may act as an accelerator or inhibitor of the enzyme systems. There is a multiplicity of enzyme systems, known and unknown, in the body. Also, there is a variability of structure and physiological activity. The enzymes are variously described as organic, frequently a protein or inorganic, a colloidal solution of a metal. Warburg's enzyme is an organic iron compound present in all tissues, and the primary factor in cell respiration. There are yellow enzymes with nine substances which take part in oxidations and reductions; all contain riboflavin. It will be seen from the above that proteins, metals and vitamins go to make up enzymes and that hormones may be component parts of an enzyme system. The importance of the pancreatic enzyme trypsin, as it may influence thrombotic lesions occurring any place in the body from the acoustic labyrinth to the extremities, has not been finally evaluated. The writer is now conducting such a study. It seems the pursuit of this investigation may be rewarding.

TREATMENT OF SPECIFIC DISEASES

Asthma. ACTH or cortisone in intrinsic asthma is definitely indicated and may be life-saving. Intravenous administration of 25 units of ACTH in 1000 ccs of 5 per cent glucose, a drop every three or four seconds. The infusions require six to eight hours to complete. Three or four such infusions, sometimes more, may be necessary. Fifteen units of ACTH in 500 ccs of 5 per cent glucose is frequently just as effective. The Thorn test for adrenal cortical function is important. In less severe asthmatic cases H. P. Acthar Gel® is the most satisfactory preparation for subcutaneous and intramuscular administration. Minimum dosage can be easily measured even in high potencies such as 80 Armour units per cc if an insulin syringe is used—H. P. Acthar Gel 40 to 60 units daily and continue two or three days as required, but reduce at least 10 more units each day

If there is any question regarding cortical function or any other contraindication to ACTH, cortisone should be tried. Start the dosage at 75 mg or less per day and reduce 10 to 15 mg each day until 50 mg is reached. The 50 mg may be necessary for a few days, but the treatment should be discontinued as soon as possible. It appears to be safe to administer 25 mg of cortisone in divided doses over rather long periods of time. Watch for danger signs! Try small doses of ACTH 10 to 15 units subcutaneously daily for a short time. Rest periods with complete withdrawal are always indicated.

Seasonal Hay Fever. Hormonal therapy has not replaced the conventional preseasonal and seasonal desensitization although they may act synergistically with allergens. The hormones ACTH and cortisone should be used if the desensitization has failed completely or in part if the patient fails to respond to the antihistamines.

Symptomatic relief can be expected in nearly all cases. The duration of the relief varies greatly from a few days to a few weeks but long enough to assure ACTH and cortisone a definite place in our therapeutic program. Short courses of treatment, frequent rest periods, low dose schedules and regular observations make it a safe procedure.

Conservative optimism and continued study will, no doubt, clarify the picture so we may soon courageously administer these hormones with less fear of a serious sequela.

The concomitant administration of the sex steroids with ACTH and cortisone is nearly always indicated in older persons.

Tension States. There is an overlapping interest, in all branches of medicine, in the tension states. So frequently they are erroneously diagnosed as a "neurosis" or a "chronic nervous exhaustion." There is almost always a general deficiency background in which the sex steroids are most prominent. Benjamin[8] believes a favorable effect of the steroid sex hormones on circulation by relaxing arterioles and capillaries has been well established. He quotes Walker, "Since impaired circulation is at the bottom of the majority of all symptoms in the aging process, a circulatory improvement would be a self-evident advantage."

The above is of vital importance in the management of many acoustic dysfunctions of vascular origin; vascular headaches such as migraine, histaminic cephalgia, and many vasospastic conditions.

If the vascular condition any place in the body is thought to be of thrombotic origin, trypsin should be considered concurrently.

Goldzieher and Goldzieher[6] believes the duration of steroid therapy in the aged should not be limited in time but continued indefinitely since it is substitutional and symptomatic. They believe interruption of therapy ends most of the benefit.

CONCLUSIONS

1) Determine, if possible, a hormone pathogenesis of the disease to be treated.

2) Make certain that conventional therapy has failed.

3) Short courses of hormonal therapy with as small a dosage as possible is a safe procedure.

4) Observe the patient frequently and be alert for danger signs.

5) There is no chemical or biological assay at this time that will determine accurately a deficiency or imbalance of the hormones.

6) The presumptive subjective diagnosis of sex steroid deficiencies or imbalances is more within the range of our present knowledge. Case history and therapeutic test injection as described are helpful, but must be considered as only suggestive.

7) Hormones should be regarded only as one deficiency. All other deficiencies should be corrected concurrently. Supply the endocrine glands with congenial and adequate chemical media and they will usually synthesize their own hormones.

8) Discontinue all hormonal therapy as quickly as possible, except in the aged. Allow rest periods as a control to determine the continued need. Adequate dynamic therapy directed toward the correction of all suspected multiple deficiencies, even though there may be no grossly apparent pathologies, is often rewarded with gratifying clinical results.

9) Accentuation must again be placed on the importance of a balanced, combined, sex hormone therapeutic regime. This is especially true of the aging individual, male or female, showing signs of degenerative changes. Considering the aging female, it must be remembered that the estrogens are for replacement or supplementation of the diminishing natural hormones, while the androgens are given

for hormonal balance, and of equal or greater moment is their anabolic action in stimulating protein synthesis to increase muscular strength; androgens may also stimulate ovarian activity.

In the management of the aging male the androgens seem most important for their physiological activity in protein building, while the estrogens are chiefly for hormonal balance. The estrogens appear to have some beneficial effect on ectodermal tissues in the male. The writer seldom prescribes one sex hormone without the other. Both are given when ACTH or cortisone is being used.

10) The oral administration of estrogen, testosterone mixtures with nutritional supplement, is worthy of much more clinical trial. Estrogenic substances probably also have a stimulating effect on the output of ACTH and protein metabolism. Estrogens may stimulate osteroblastic activity and many cause an increased loss of hearing in women with otosclerosis during child-bearing periods. Testosterone, a known antimetabolic, might be indicated.

11) Hormonal therapy alone is never curative, usually helpful when indicated; always potentially dangerous and probably has great dormant possibilities as a new therapeutic tool when completely understood. At the present time hormones are of distinct value in the management of refractory allergic conditions in the tension states and probably are of value in certain degenerative changes occurring in the aging individual.

12) The androgenic hormones are chiefly of value as powerful protein anabolic agents, retaining nitrogen and building up protein. They are, therefore, the most universally accepted steroids for use in both sexes. When indicated, the estrogens and progesterones have a mildly anabolic action. The mechanism of this anabolic action is still unknown.

13) Clinical judgment is extremely important. One would not, of course, advise the androgens for women who already have obvious signs of masculation such as dark hair with masculine distribution, oily skin and large bony frame. Neither would one suggest estrogen for women of the opposite type, unless specific indications were present.

14) Complete failure or, at least, disappointing results are almost sure to follow the correction of only one deficiency whether it be hormonal, nutritional or electrolyte.

Fig. 1.—Recurring intraorbital hemorrhage.

If the body metabolism has been such as to produce a deficiency in one hormone it most probably has depressed other endocrine secretions. Hormones have a synergistic action. The same is probably true of vitamins and minerals. I am willing to endorse the postulation that there is a harmonious interaction among hormones, vitamins and electrolytes. This is probably both catalytic and synergistic. They all form and function as enzymes. The enzyme trypsin is worthy of much more study.

REPORT OF A CASE

Only one case report is appended because well-founded knowledge of therapeutic results in hormonal therapy is still fragmentary. Conclusions may be premature, perhaps even fallacious. Criteria for evaluation is not well-defined. Other case reports will appear with another publication soon to follow.

Mrs. F. W. McR., aged 60 years, had seven intraorbital hemorrhages of unknown etiology from May 1 to September 15, 1953. The first attack occurred while she was sitting at a sewing machine. She appeared to have a "black eye," without much pain. The after effects of this hemorrhage lasted only a few days. The second episode, four weeks later, was much more severe and more painful. Blood oozed into the inner canthus through the lacrymal duct. Severe nasal hemorrhage was followed by nausea and vomiting of a large quantity of dark blood. She was admitted to a nearby hospital for a week. The third attack occurred in the early part of July and was even more severe. The vision in the left eye did not return when th swelling subsided as it had previously done. The other attacks

came on periodically until the middle of September when the seventh and last attack occurred; it was much less severe in every way. The patient's condition was as tragic as it was dramatic. She was seen by many consultants including an eminent neuro-surgeon.

Her menarche had begun at the age of 12 years. Almost from the beginning she had had severe menalgia which required bed rest and some sedation. Even as a child she passed large clots which usually relieved much of her menstrual discomfort. She has had a very painful hypertrophic arthritis for 26 years.

She had had five pregnancies: the first child was born when she was 17 years of age; the last child when she was 45. When she became pregnant the last time, 16 years ago, and for five years afterward, she had almost complete relief from her painful arthritis. However, it then returned with renewed severity.

During her menopause she had three severe uterine hemorrhages requiring long periods of bed rest and "shots" to control bleeding. These attacks occurred about once a year over a three-year period.

At the suggestion of another otolaryngologist I had the privilege of seeing this patient on August 4, 1953, after the fifth orbital hemorrhage had occurred. Her otolaryngological findings were negative. All laboratory findings including a left carotid angiograph were negative. Blood examinations revealed only a secondary anemia as would be expected.

She had seven transfusions which gave her some increase in strength but did not influence recurring hemorrhages. She had been given large quantities of antibiotics as one consultant proposed a diagnosis of erysipelas. Several hours were spent getting the gynecological history, and the presumptive diagnosis of an estrogenic deficiency or imbalance was made on the history alone. There were no other findings to substantiate this opinion. For academic reasons and to determine a single deficiency if possible, the patient was placed on oral estrogens (liquid premarin) on August 6, 1953. There was a marked improvement in her arthritic pain. She was able to walk around the ward and to take care of herself. She was euphoric and so were her physicians. This euphoric period lasted only a few days, after which her arthritic pain returned with increased severity.

On August 14, 1953, she had another severe intraorbital hemorrhage. She was put on cortisone, combined with the estrogenic substance, vitamins, minerals and an adequate nutritional regime plus

dilute hydrochloric acid. She is now continuing all therapy as outlined and her family physician is giving her ACTH for her arthritis. She has had no recurrence of the orbital hemorrhages.

Comment. It is, of course, impossible to conclude that her recurrent orbital hemorrhages were due to a steroid deficiency or imbalance. It is much more likely there was a general deficiency existing, including the steroids.

The gynecological history was strongly suggestive. The clinical results were quite convincing. An attempt to manage her therapy on a single deficiency basis proved futile. The balancing and correcting of all deficiences seems to have been the proper clinical procedure. Her digestion and assimilation seem to have been greatly improved by the addition of dilute hydrochloric acid. The writer is in complete agreement with Hewlett and Scott,[9] who believe that "cortricotropin and cortisone exert a beneficial effect on capillary fragility and bleeding phenomena in various types of thrombocytopenia. The improvement is not necessarily associated with an increase in circulating thrombocytes."

1110 Professional Bldg.

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SCIENTIFIC PAPERS OF THE AMERICAN OTOLOGICAL ASSOCIATION

(Continued from June issue)

LII

DIFFERENT TYPES AND DEGREES OF ACOUSTIC TRAUMA BY EXPERIMENTAL EXPOSURE OF THE HUMAN AND ANIMAL EAR TO PURE TONES AND NOISE

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Experimental exposure of the human ear to pure tones and noise should clarify the problem of temporary deafness due to acoustic trauma, which is important during peacetime as well as war. Exposures of the animal ear were and still are essential in examining the morphological, that is the definite alterations, in the inner ear. The experimental findings of an American group under the direction of Hallowell Davis and M. H. Lurie[4] and our independently conducted experiments coincide for the most part and in some ways supplement each other. We have therefore summarized these experiments on human and guinea pig ears in two tables. The sequence of the tests is determined by the intensity of the tones (db) noted in the center column, since according to Davis, it is primarily the intensity of the tone that is crucial in the causing of an acoustic trauma, while the time factor (t) and the frequency (cps) are only of secondary significance. Several further experiments concerning the beginning stage of noise deafness, which should be discussed today are also included in the table. The fragile construction of the inner ear of the guinea pig is much more vulnerable then the more strongly constructed human ear. Loud tones and noises, which in the guinea pig ear cause visible damage to the organ of Corti after only short

From the Oto-Rhino-Laryngological Clinic of the University of Zürich.

GUINEA PIG					MAN				
Pure tone			Noise		Pure tone			Noise	
c/s	t	db	t	c/s	c/s	t	db	t	c/s
500 D.L	3'	153-144			65oo D.	5'	159-158		
1000 D.L	3'	149-140			10000 D.	5'	153		
4000 D.L	1' - 4d'	145			14500 D.	3,9'	154		
2000 D.L	15' - 6'	145-134							
7000 R.F	50h - 70h	140	2' to 8h	white noise II	800 R.F	3'	140		
4500 R.F	17h - 132h	140			1200 R.F	3	135		
1600 R.F	64h - 188h	140			270 R.F	5	135		
800 R.F	35h - 49h	140			7000 R.F	3'	130	1'2'4'8'16'32'	white noise II
600 R.F	23h - 48h	140			6000 R.F	3'	130		
400 R.F	4h - 34h	140			4000 R.F	4'	130		
270 R.F	6h - 50h	140							
		130	2' to 8h	white noise II					
					2000 D.L	1'2'4'8'16'32'	130		
					1000 D.L	1'2'4'8'16'	130		
					500 D.L	1'2'4'8'16'32'	130		
					2000 B.L	1'2'	125		
					4000 D.L	1'2'4'8'16'	120	1'2'4'8'16'32'64'	white noise II
					2000 D.L	1'2'4'8'16'32'	120		
					1000 D.L	1'2'4'8'16'32'64'	120		
					500 D.L	1'2'4'8'16'32'64'	120		
					4000 D.L	1'2'4'8'16'32'	110	4'8'16'32'	white noise II
					2000 D.L	1'2'4'8'16'32'	110		
					1000 D.L	4'8'16'32'	110		
3200 R.F	96h - 445h	100	1'2'4h - 2'34'2h	noise 175a - 5600a			105	2'	white noise R.
800 R.F	638h - 846h	100					100	2'4'8'	white noise R.
350 R.F	484h	100					95	2' ↶	white noise R.
							90	2' ↶	white noise R.
							85	2' ↶	white noise R.
							80	2'	white noise R.

Fig. 1.—Table. Experimental exposures of the human ear and the guinea pig to pure tones and noise by H. Davis, M. H. Lurie and co-workers (D. L.) and by Rüedi and W. Furrer (R. F.)

exposure, are tolerated without a definitive functional loss by the more resistant human ear. The experimentally produced morphological changes in the animal ear are equivalent to a final stage of damage whereas the reversible hearing losses produced in the human ear only characterize a beginning acoustic trauma. Nevertheless the histological changes in the guinea pig give an indication of similar definitive changes in the human ear, presupposing that an equivalently high acoustic trauma occurs. Unfortunately the functional tests of the animal ear by means of the Preyer auricle reflex, or measuring the aural microphonics, yield inaccurate results which do not parallel the anatomical changes.

The histological changes in the animal ear can be divided into three degrees according to the extent of damage. The following findings are characteristic for the various degrees of pure tone trauma on the one hand and a noise trauma on the other:

Fig. 2.—Organ of Corti of guinea pig. Exposure to pure tone 6600 cps, 140 db, for 8 minutes.

THIRD DEGREE MORPHOLOGICAL CHANGES IN THE GUINEA PIG EAR

a) Pure tone trauma (intensity 145-150 db, exposure time 3,′ frequency 500, 1000, 2000 and 4000 cps) (Fig. 1). Immediately after exposure there were tears in the supporting structure of Corti's organ, a stripping off of the mesothelial cells and possibly bleeding into the scala of the cochlea. Several weeks later Corti's organ was altogether absent from the damaged area. The corresponding nervous tissue showed an ascending degeneration. The damaged area always extends over several windings. Tones of higher frequency disrupt Corti's organ in the lower winding near the window, lower tones, the upper windings.

b) Noise trauma (intensity 140 db, exposure time 3′ to 60′) (Fig. 2) caused immediately after exposure the same injuries to Corti's organ. Subsequently Corti's organ disappears in all the windings, and the corresponding nervous tissue degenerates.

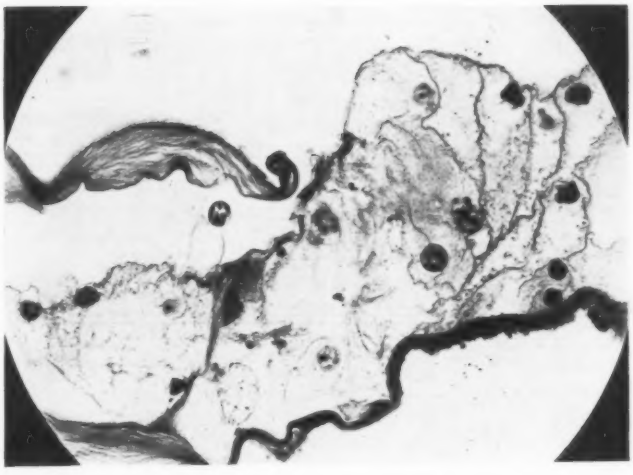

Fig. 3.—Cochlea of guinea pig. Exposure to white noise, 140 db, for 8 minutes. Histologically controlled 4 weeks later.

Whereas pure tone trauma damages only a certain, however wide area of the windings, an intensive noise trauma involves all the windings.

SECOND DEGREE MORPHOLOGICAL CHANGES IN THE GUINEA PIG EAR

a) Pure tone trauma (intensity 140 db, exposure time 1 to 188 h, frequency 270, 400, 600, 800, 1600, 4500 and 7000 cps) caused in the initially intact Corti organ a loss of first the outer, then the inner hair cells (Fig. 3). In the course of several weeks the organ of Corti was resorbed and the nervous tissue degenerated. Following trauma with high tones the morphological changes were located in the lower windings, low tones damaged a wide zone in the upper cochlear windings.

With the same trauma (Fig. 4) there was considerable individual variation in the degree and extent of inner ear damage in the various guinea pigs.

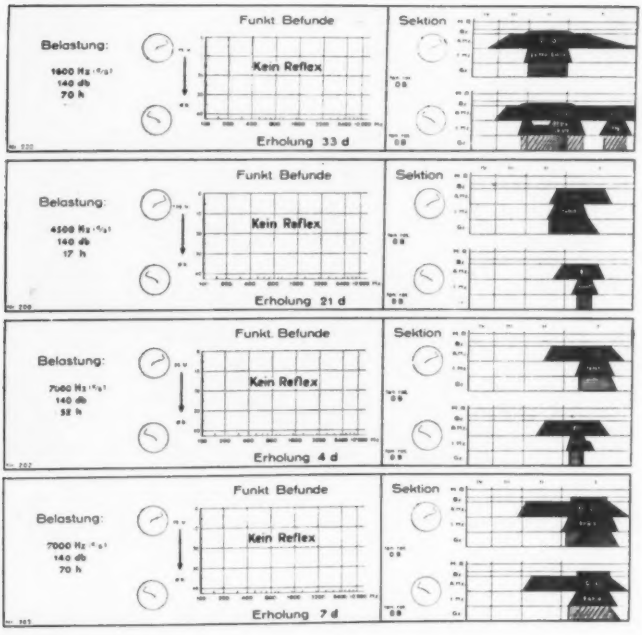

Fig. 4.—Charts showing functional and histological findings in guinea pigs traumatized by pure tones 600-7000 cps, 140 db, 17-70 hours. The second half of the diagram gives the post-mortem findings in the unrolled cochlea, represented by a band divided into four layers. The histologic changes are entered as black patches.

b) Noise trauma (intensity 130 db, exposure time 8 h) also destroyed first the inner then the outer hair cells and then resorption of Corti's organ in the entire cochlea in contrast to the correspondingly loud pure tone trauma.

FIRST DEGREE MORPHOLOGICAL CHANGES IN THE GUINEA PIG EAR

a) Pure tone trauma (intensity 100 db, exposure time 94 to 445 h, frequency 800 cps and 3200 cps) caused a loss of the outer

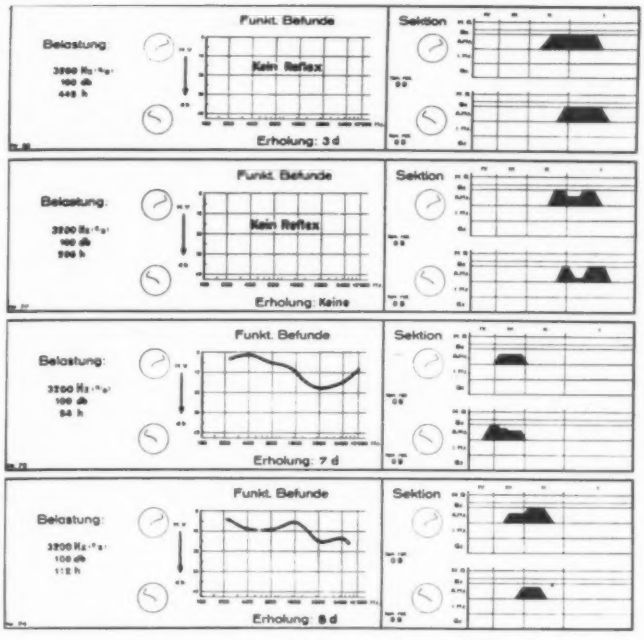

Fig. 5.—Charts showing functional and histologic findings in guinea pigs traumatized by pure tone 3200 cps, 100 db, 94-445 hours.

hair cells (Fig. 5). With serious exposures the hair cell loss showed strong individual variations as to extent and localization.

b) Noise trauma (intensity 100 db, exposure time 1771 to 2347 h) caused a loss of the outer hair cells (Fig. 6) which in contrast to a pure tone trauma, was consistently located in the same area, from the end of the first winding to the middle of the second. Consequently the pure tones and noise of high intensity cause an immediate tearing of Corti's organ and with less intensity a gradual degeneration of the hair cells in the guinea pig ear. Depending on whether it was a pure tone trauma or a noise trauma these, for the most part identical morphological changes, were localized in various areas and to various extents in the cochlea.

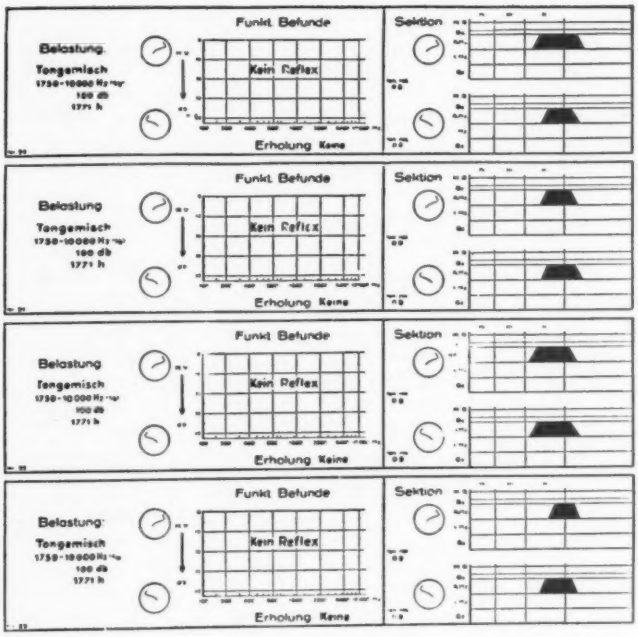

Fig. 6.—Charts showing functional and histologic findings in guinea pigs traumatized by noise.

The experimental exposure of the human ear also varied to various degrees.

THIRD GRADE FUNCTION LOSS OF THE HUMAN EAR

a) Pure tone trauma (intensity 151-159 db, exposure time 3½′ to 5,′ frequency 6500 cps, 10,000 cps and 14,000 cps) as was used by Davis and his co-workers in inspiring experiments, caused in two test individuals a definitive hearing loss in the higher tone areas and once an ear drum injury. With that the "threshold for mechanical injury of the middle ear and also probably for the production of permanent hearing loss" was reached or already exceeded.

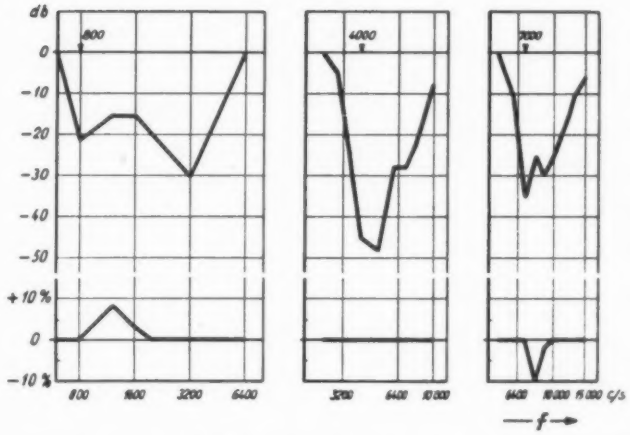

Fig. 7.—Damage of the human ear with pure tones of 800, 4000 and 7000 cps at intensities of 130-140 db, for periods of three to four minutes. Above: hearing loss; below: alteration in pitch.

b) Noise trauma with similarly high intensities were fortunately not tried on human subjects.

SECOND GRADE FUNCTION LOSS OF THE HUMAN EAR

a) Pure tone trauma (intensity 110-130 db, exposure time 1′ to 32,′ frequency 270, 500, 1000, 1200, 2000, 3000, 4000, 5000, 6000, and 7000 cps) caused individually different amounts of hearing loss, whereby the hearing loss extended from a little below or a little above the frequencies of the exposed tones to two to three octaves above these frequencies. Hence the maximum hearing loss lies one-half to one octave above the demaging frequency (Fig. 7). After such exposure diplacusis developed in certain individuals. This traumatic change of pitch can be measured. Pure tone exposure below a frequency of 4000 cps caused a pitch elevation of 90 per cent, tones above 4000 cps on the other hand caused a lowering of pitch. Peculiarly the tone 4000 cps caused no pitch change.

b) Noise trauma (white noise) (intensity 130 db, exposure time 1′ to 32′) caused a hearing loss that usually began at the fre-

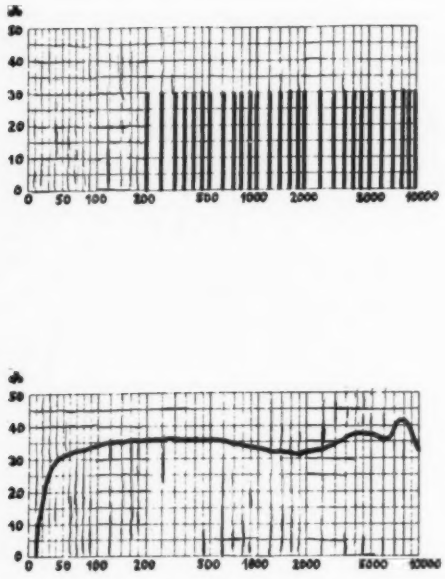

Fig. 8.—Above: Spectrum of noise voltage of the noise generator in the Békésy audiometer; below: Acoustical frequency response of the Békésy audiometer with the dynamic earphone type "Standard" 4026A.

quency 500 to 1000 cps and extended over 3 to 4 octaves. The maximum hearing loss is most frequently localized in the area of 4000 cps to 6000 cps, which is why we speak of a c^5 or c^6 dip. The temporary noise deafness varies in degree and recovery time inter- and intraindividually quite a bit. Diplacusis, that is a pitch change, is very rarely found following experimental noise trauma.

It can be shown from these reversible hearing losses produced in the human ear that there is a difference in pure tone trauma and noise trauma.

The American and Swiss groups did not undertake any investigation concerning first-grade functional losses of the hearing at that time. The significant addition to this question was contributed by

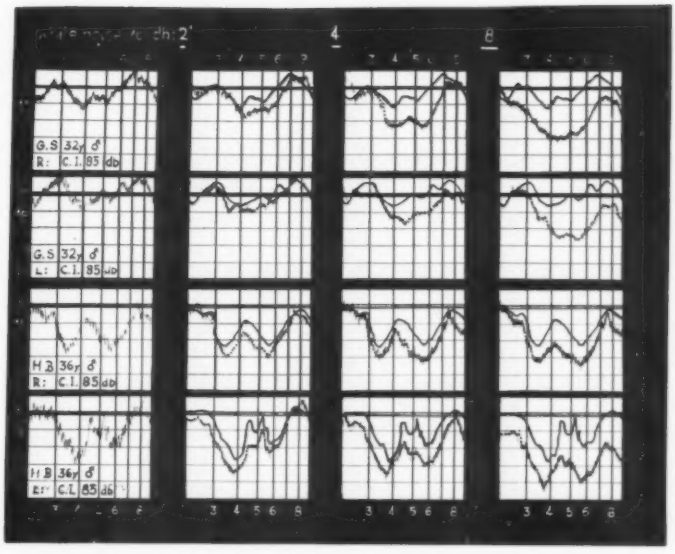

Fig. 9.—Individual hearing losses (Békésy audiograms) after the exposure to white noise (100 db) for 2 minutes, 4 minutes and 8 minutes.

J. D. Hood[10] in 1950 in his pure tone experiments. With the help of equipment constructed by C. S. Hallpike and C. H. Schuster producing a continuous audiogram, the variation of perstimulatory and poststimulatory fatigue with stimulus duration, intensity and frequency has been investigated. Accordingly perstimulatory fatigue is a physiological decline in sensitivity of the hearing receptors following their physiological activity. Perstimulatory fatigue is independent of the intensity of the stimulus. This phenomenon would more suitably be called perstimulatory adaptation. In contrast to that the poststimulatory fatigue varies with intensity and there exists a critical fatiguing intensity (95 db at 2048 cps) which makes an important dividing line between fatigue of a physiological nature and fatigue of a pathological nature. There exists no comparable critical duration of the fatiguing tone.

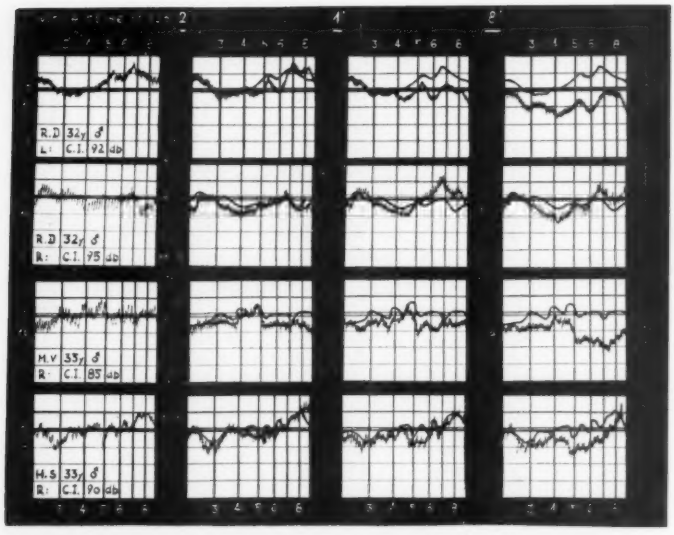

Fig. 10.—Individual hearing losses (Békésy audiograms) after the exposure to white noise (100 db) for 2 minutes, 4 minutes and 8 minutes.

Following these pure tone experiments of J. D. Hood our objective was to further clarifying the beginning of stimulation deafness, that is, the transition of physiological to pathological fatigue. Considering the c^5 dip typical for noise trauma, we chose the pure tone 4000 cps as a test tone in an experimental set-up yet to be discussed. In contrast to this J. van Gool[9] and H. A. E. van Dishoeck[5, 6] found with the continuous audiogram in noise deafened persons two-thirds of all the dips localized in frequencies higher then 4096 cps and that there existed no preference for the c^5. These authors came to the conclusion that "the notion of the c^5 dip as a typical symptom of stimulation deafness depends upon a measuring error in the octave audiogram because the frequency area of 4000 cps to 8000 cps is insufficiently tested by this method."

To clarify this contention the following experiment was conducted:

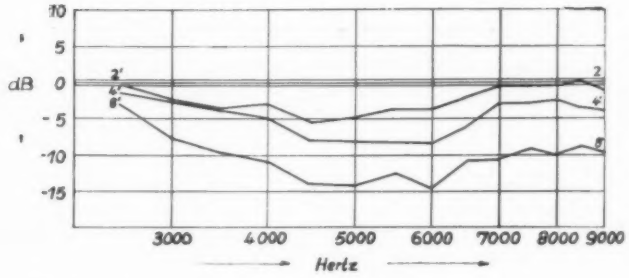

Fig. 11.—Average hearing losses (8 ears) after the exposure to white noise (100 db) for 2 minutes, 4 minutes and 8 minutes.

First test: As subjects for our hearing tests we employed a group of eight ear, nose and throat doctors and two technicians, trained in audiometry, between 24 and 53 years of age. All were in good general health. All showed normal auditory function and practically normal audiograms. Only one subject (O. H.) had a special sensitivity for noise.

Apparatus: We used a Békésy[1] audiometer. In this audiometer we have a white noise generator (Fig. 8), the noise of which has a frequency spectrum from 10-30,000 cps. In this frequency range the distribution of the energy is linear. Pure tone and white noise are given to the same ear phone, which has a practically linear frequency response from 200-19,000 cps. The intensity of the pure tone can be controlled by the test subjects in the manner of Békésy and is held at the threshold.

Technique: A normal Békésy audiogram is made. Then follows an exposure to white noise (100 db) for 2.′ A second Békésy audiogram is made and again the subject is exposed to white noise (100 db) for 4.′ A third audiogram is made. Finally there is a last exposer to white noise (100 db) for 8′ and last a fourth Békésy audiogram is made.

RESULTS

The threshold curve of eight ears from five subjects following these exposures are showed in Figures 7 and 10. The straight black curve represents the prestimulatory normal hearing, the dotted black

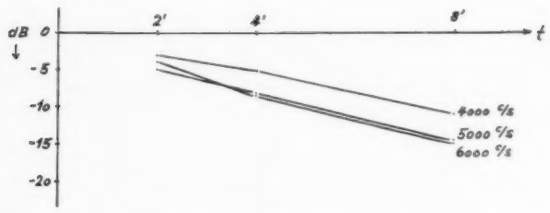

Fig. 12.—Pathological fatigue (stimulation deafness) of the tones 4000 cps, 5000 cps, 6000 cps after exposure to white noise (100 db) for 2 minutes, 4 minutes and 8 minutes.

line the poststimulatory threshold between 2000 and 8000 cps. These original curves show with constant intensity of the noise a hearing loss, which increases with the exposure time. The large and flat dip between 2000 and 8000 cps varies individually as far as the slope of the curve and the maximum hearing losses are concerned.

After 2′ of white noise (100 db) the greatest hearing loss lay between 5-15 db

at 4500 cps in 5 ears
at 6000 cps in 1 ear
at 9000 cps in 1 ear.

After 4′ of white noise (100 db) the greatest hearing loss lay between 8-18 db

at 4500 cps in 3 ears
at 5000 cps in 1 ear
at 5500 cps in 2 ears
at 6000 cps in 1 ear
at 7000 cps in 1 ear.

After 8′ of white noise (100 db) the greatest hearing loss lay between 8-25 db

at 4000 cps in 2 ears
at 4500 cps in 1 ear
at 5000 cps in 1 ear
at 5500 cps in 1 ear
at 6000 cps in 1 ear
at 7500 cps in 1 ear
at 9000 cps in 1 ear.

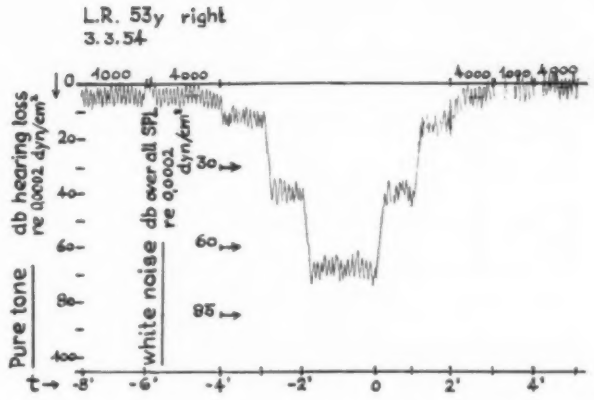

Fig. 13.—Threshold for pure tone 1000 cps before and after exposure to white noise for 2 minutes, and threshold for pure tone 4000 cps before, during and after exposure to white noise for 2 minutes.

Two subjects (G. von Sch. and H. B.) show similar losses on both ears. One subject (R. D.) shows a different localization and a different degree of hearing loss. Figure 11 shows the average loss of these eight ears. In general the loss begins at 2000 cps and reaches a first maximum of totally 28 db at 4500 cps, a second maximum of 25 db at 5000 cps and a third maximum of 27,35 db at 6000 cps (Fig. 12). By constant pressure and frequency the fatigue response in db seems to be a linear function of the exposure time.

The white noise (100 db) caused a wide dip encompassing 2 octaves. The contention put forth by H. A. E. van Dishoeck and J. van Gool that the hearing loss due to noise deafness lies above c^5 as a rule was confirmed to a certain extent. Still a flat dip occurring between 2000-8000 cps should be considered typical for the beginning stage of a noise trauma. Therefore the pure test tone of 4000 cps seemed to us quite suitable for investigating the beginning noise trauma. For future investigations however we prefer a test tone of 500 cps.

Second Test: *The same subjects and the following apparatus*: We used the same Békésy audiometer. The only difference consisted

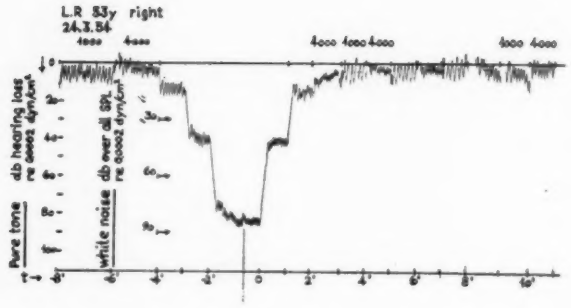

Fig. 14.—Threshold for pure tone 1000 cps before and after exposure to white noise for 2 minutes, and threshold for pure tone 4000 cps before, during and after exposure to white noise for 2 minutes.

in replacing the pure tone generator of the audiometer with another independent one. By this means the test subject got the frequencies of 1000 cps or 4000 cps alone or combined with the white noise. The intensity of the respective pure tone can be held at the threshold by the test subject himself.

We calculate the energy of the noise as follows: Bandwidth of white noise from 200-10,000 cps = 10,000 cps. Over-all SPL = 100 db re 0,0002 dyn/cm^2. SPL per cycle = 100 db – log 10,000 = 100 db – 40 db = 60 db per critical bandwidth 4000 cps resp. 1000 cps = 23 db more resp. 17 db more (in sum 83 db resp. 77 db = ca. 80 db). This value corresponds to the curve which masks a pure tone of 4000 cps at 100 db of an over-all SPL.

The threshold for 4000 cps and a second test tone 1000 cps is registered before, during and after the exposure to a well-defined white noise. The transference from the quiet of the sound-proof room into the two minute noise exposure and the removal from noise was done in two noise stages of 30 db and 60 db.

RESULTS

Subject: *L. R. 53 years of age. Right ear*: a) White noise (85 db, exposure time: 2′) (Fig. 13). The pre- and poststimulatory threshold for 4000 cps showed no change of the difference limen.

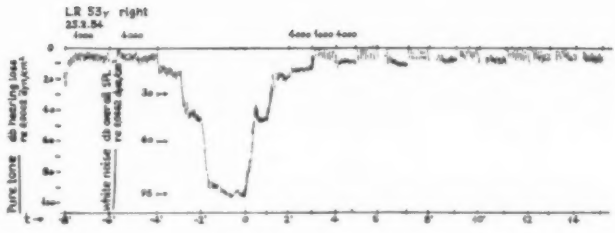

Fig. 15.—Threshold for pure tone 1000 cps before and after exposure to white noise for 2 minutes, and threshold for pure tone 4000 cps before, during and after exposure to white noise for 2 minutes.

After cessation of the noise there was a bilateral tinnitus, which rapidly decreased with removal from noise (1′ 60 db, 1′ 30 db). Recovery of hearing for the test tone 4000 cps required 4½′ from cessation of the white noise till the prestimulatory threshold was reached. Difference limen and threshold of the second test tone of 100 cps were not influenced by exposure to white noise (85 db).

b) White noise (90 db, exposure time: 2′) (Fig. 14). During the exposure a narrowing of the difference limen of the test tone 4000 cps occurs. The narrowing of the difference limen is demonstrable for 7′ following cessation of the white noise (90 db). An initial bilateral tinnitus, which was then noted more strongly in the unexposed ear, decreased gradually. Complete threshold recovery for 4000 cps occured within 4½′ after cessation of the white noise (90 db). Difference limen and threshold of the second test tone 1000 cps were not influenced by exposure to the white noise.

c) White noise (95 db, exposure time: 2′) (Fig. 15). The narrowing of the difference limen during the noise exposure became more noticeable and can be demonstrated for 17′ following cessation of the noise. Immediately after the noise ceased a stronger, higher tinnitus was noted in the second unexposed ear. During removal the hearing for 4000 cps recovered quickly at first up to the last 30 db noise level endured. After this remaining noise was halted recovery was delayed. Only after 15′ was the prestimulatory threshold of 4000 cps reached. And now the threshold for the second test tone of 1000 cps was altered by exposure to noise, and paradoxically it was

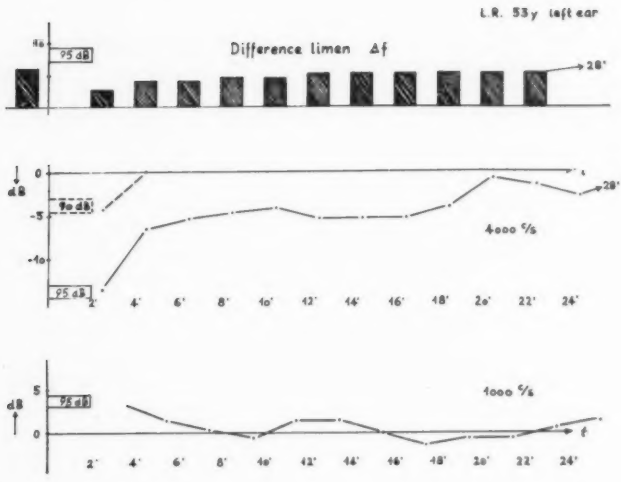

Fig. 16.—The three typical symptoms of a beginning stimulation deafness. Narrowing of the difference limen ($\triangle$ f), prolonged recovery for 4000 cps, lowering of the threshold for 1000 cps.

lowered. The sensitivity of the traumatized ear for the test tone 1000 cps was therefore increased by the noise trauma.

Same subject. Left ear: With the same technique the transition from a physiological fatigue, disappearing in 4½′, to a protracted pathological fatigue, that is stimulatory deafness, was determined. This transition occurred abruptly here also, just above a noise intensity level of 90 db. At the noise intensity of 95 db the pathological symptom of a narrowing of the difference limen once again appeared, accompanied by a delay in the hearing recovery of over 28′ for the test tone 4000 cps, 3½′ following exposure to noise the threshold for the second test tone 1000 cps was lowered 4 db, so that this tone was now heard better then before traumatization with noise.

The tests (Fig. 16) conducted on nine other subjects with the identical technique yielded results which coincided with the example described showing the characteristic hearing changes of noise deafness. Noise stimulation deafness begins regularly with a narrowing of the

C.F. ♀ 24 y	r – l 78 db
O.H. ♂ 32 y	r 80 db l 80 db
M.V. ♂ 33 y	r 85 db l 80 db
H.D. ♂ 31 y	r – l 85 db
G.S. ♂ 33 y	r 85 db l 85 db
H.B. ♂ 36 y	r 85 db l 85 db
L.R. ♂ 53 y	r 90 db l 90 db
H.S. ♂ 35 y	r 90 db l
H.V. ♀ 45 y	r – l 95 db
R.D. ♂ 33 y	r 95 db l 92 db

Fig. 17.—Critical intensity level noise in 16 ears of 10 subjects.

difference limen. An increased intensity of white noise is followed with some individual variations sooner or later by a pathological delay in recovery of the threshold for the test tone 4000 cps, accompanied by a lowered threshold for the second test tone 1000 cps. Due to abrupt transition of physiological fatigue to stimulation deafness the threshold of white noise, that is the intensity of noise which the test subject can maximally tolerate without pathological hearing loss, can be very precisely determined. The table (Fig. 17) gives information as to the critical intensity level (C. I.). In this small group alone there are considerable individual variations up to 17 db. In six of the bilaterally tested individuals two showed a difference of C. I. from one side to the other. In the noise sensitive subject O. H. the C. I. of 89 db on both sides is on the lower limits.

Third Test: Determinations of the C. I. in the same subject on different days and with differences of general disposition show fluctuations of 5 db.

For example in L. R. just after a grippe the C. I. was 85 db, where before it was 90 db, to which it returned after a two week convalescence.

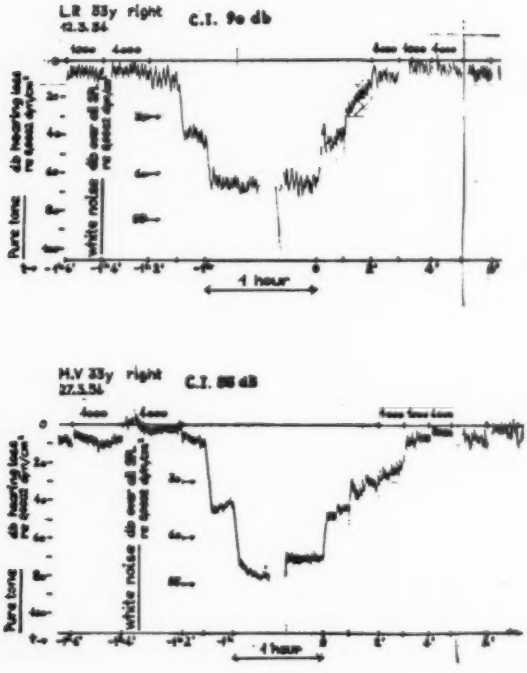

Fig. 18.—Threshold for pure tone 1000 cps before and after exposure to white noise for 1 hour, and threshold for pure tone 4000 cps before, during and after exposure to white noise for 1 hour.

Fourth Test: The first test has shown that a constant noise of an intensity above the C. I. of 100 db causes stimulation deafness, which expressed in db, increases a linear function of the exposure time.

We now exposed our subjects to white noise of critical intensity —5 db for one hour. Figure 18 contains two audiograms of subjects so exposed. In both cases the white noise was tolerated for one hour without any sign of stimulation deafness. Consequently there is no critical duration of the fatiguing tone under the critical noise intensity. Thereby the findings of Hallowell Davis and J. D. Hood

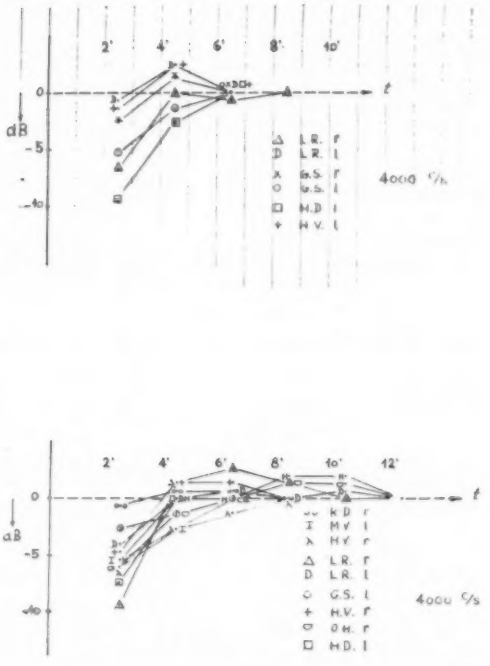

Fig. 19.—Above: Recovery for pure tone 4000 cps after white noise of C. I.—5 db, 2 minutes; below: recovery for pure tone 4000 cps of C. I. 2 minutes.

that "stimulus intensity seems to be the vital factor which determines the difference between the physiological condition of auditory fatigue and the pathological condition of stimulation deafness," were once again verified.

Fifth Test: The critical transition to stimulation deafness correlated to noise intensity has been controlled exposing our subjects for 2′ to white noise of intensity below, at and above the critical level (Fig. 19).

After exposure up to the critical intensity the curves returned to the pretraumatic hearing threshold for the test tone 4000 cps, at

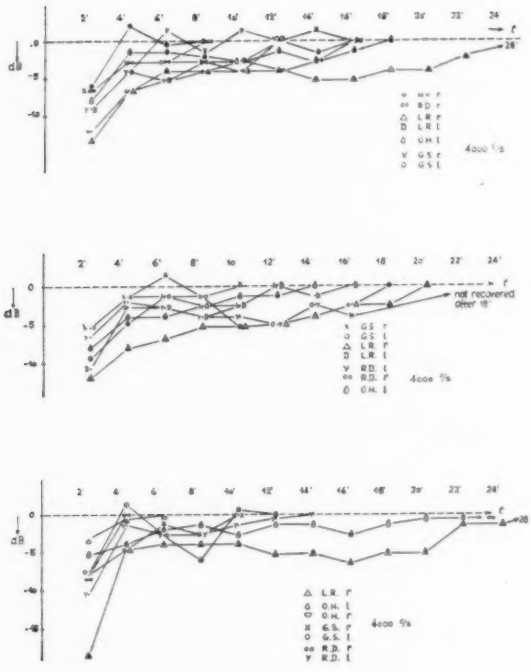

Fig. 20.—Above: Recovery for pure tone 4000 cps after white noise of C. I. + 5 db 2 minutes. Middle: Recovery for pure tone 4000 cps after white noise of C. I. + 10 db 2 minutes. Below: Recovery for pure tone 4000 cps after white noise of C. I. + 15 db 2 minutes.

most within 6½ minutes after cessation of the white noise. After noise exposure (Fig. 20) above the critical intensity (exposure time: 2′) (C. I. + 5, +10, +15 db) there occurs within 2½′ after cessation of the white noise a deeper starting but likewise as steep a curve of recovery for 4000 cps. However, when the prestimulatory threshold is reached the recovery decreased to varying degrees individually. The sound sensitive subject O. H. and the oldest subject in the test group are quite a bit behind the others. Only now clear individual difference in noise sensitivity, as shown in the varying curves of recovery, become evident.

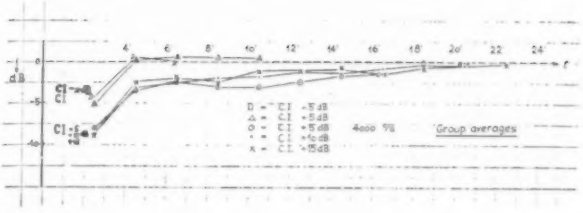

Fig. 21.—Average recovery of 6 to 8 ears after exposure to white noise at or below and above critical intensity (C. I.).

The average curves (Fig. 21) of these different groups show the physiological fatigue of the test tone 4000 cps below the critical intensity level and the pathological fatigue or stimulation deafness above the critical intensity for white noise.

Sixth Test: (Fig. 22) The same test subject exposed on different days to the same white noise shows some differences of the recovery time of the test tone 4000 cps.

A white noise (C. I. + x db) damages in the first place the peripheral hearing organ. As derived from histological changes experimentally produced in the animal ear the outer hair cells are damaged first. The narrowing of the difference limen and the initially steep, then suddenly decreased recovery of hearing for the test tone 4000 cps, also speaks for damage to the hair cells, that is for pathological functional damage of those groups of hair cells that record the softest tone. The large interindividual differences in the critical noise intensity necessary to produce stimulation deafness may possibly depend on the structural differences of the sensory hairs and the supporting framework of Corti's organ. However, since the C. I. varies within the same individual depending on momentary condition of the subject and the stimulation deafness produced under the same conditions on varying days also varies intraindividually, there come into the etiological question of stimulation deafness not only physical factors but also metabolic disturbances.

The simultaneous occurrence of better hearing for the second test tone 1000 cps corresponds to a similar observation of J. D. Hood following a pure tone trauma. J. D. Hood writes: "A rather inter-

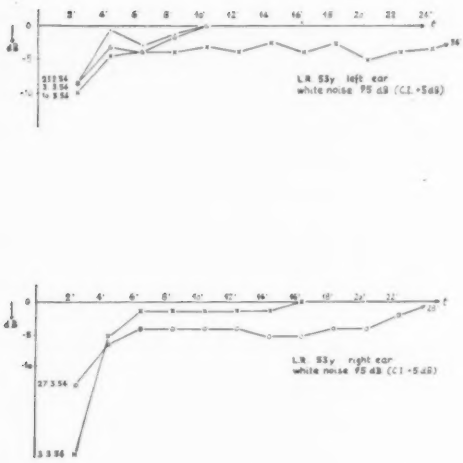

Fig. 22.—Above: Recovery for pure tone 4000 cps on different days. Below: Recovery for pure tone 4000 cps on different days.

esting observation is the fact that a few frequencies immediately below that of the fatiguing frequencies the ear exhibits a certain hypersensitivity the threshold at these few frequencies instead of being raised by the fatiguing tone is actually lowered." To explain this phenomenon he continues: "This finding is in agreement with the work of R. Galambos and H. Davis[7] on the active potential exposure from single auditory new fibres." According to these writers "a brief silent period, during which spontaneous activity is absent, occurs upon cessation of stimulation. Following very intense stimuli the silent period may be succeeded by a period of marked acceleration of the spontaneous discharge."

Despite all efforts for explanation the hearing loss above the damaging frequency with a change of pitch typical for the pure tone trauma, is still as enigmatic as the 4000-6000 cps dip, typical with noise trauma.

The clinical value of the tests described for noise sensitive individuals is being examined at the present time.

SUMMARY

On the basis of experimentally produced histological changes in the animal ear and temporary deafness in the human ear, pure tone trauma and noise trauma are different forms of acoustic trauma. Also in the first stage of noise trauma as in pure tone trauma the transition of physiological fatigue to pathological fatigue or stimulation deafness, occurs abruptly above an individually varying critical intensity for white noise. The noise stimulation deafness is characterized as follows:

a) Occurrence of a wide dip encompassing two octaves between 2000-8000 cps, with the maximum between 4000 and 6000 cps,

b) a narrowing of the difference limen of a test tone within the dip (4000 cps),

c) a delayed recovery of the threshold of tones in the region of the dip,

d) an increase of the difference limen of a second 1000 cps, that is a tone from the frequency range immediately below the noise dip;

e) a lowering of threshold for the second test tone 100 cps;

f) the stimulation deafness occurring above the individually varying critical noise intensity varies also individually.

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LIII

REGIONAL HEARING LOSSES FROM INDUCED COCHLEAR INJURIES IN EXPERIMENTAL ANIMALS

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By several techniques it has been shown that there is an orderly spatial arrangement of frequency response within the cochlea. Considerable information has been acquired by recording from the cochlea the distribution and magnitude of physical and electrical responses to pure tones. (No attempt has been made to cite all the pertinent investigations. Representative studies are listed in the references.) Another method of acquiring similar information is that of creating cochlear lesions and recording the effect on pure tone auditory thresholds. We used the latter technique in the present experiment, making the cochlear lesions as small as possible in the hope that the evidence thus acquired would yield information not only on specific frequency localization, but on the sharpness of tuning for these frequencies. We reasoned that the degree of frequency analysis accomplished by a place principle of cochlear function is greater when a particular cochlear lesion affects a band width of one octave than if that band width were several octaves. We believe our failure to demonstrate sharper tuning in previous experiments was due to the inability to create more

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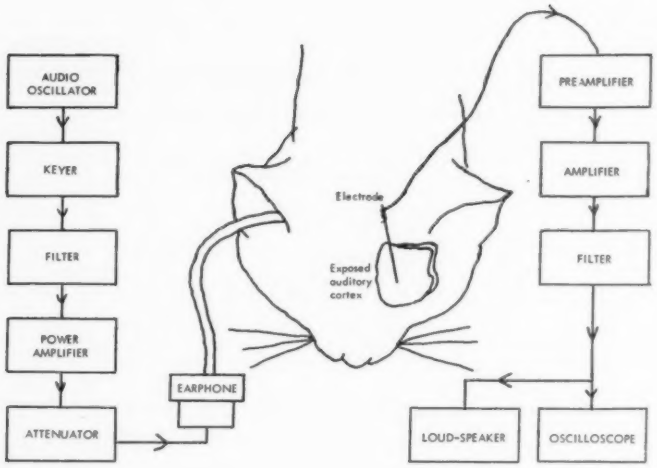
To be presented by Mr. Sutton in partial fulfillment of requirements for the degree of Doctor of Philosophy in the Department of Psychology, University of Chicago.

Dr. Schuknecht was formerly Assistant Professor, University of Chicago School of Medicine. Now Associate Surgeon, Division of Otolaryngology, Henry Ford Hospital.



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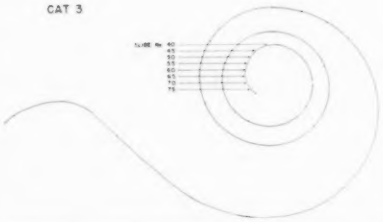

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Fig. 1.—Top: Diagrammatic sketch of cortical testing technique. Bottom: Sketch to show method for study of cochlea. A cochlear reconstruction is made first. A detailed study is then made for each cut through the cochlear duct and pathological changes recorded on charts as shown. (See Table 1.)

restricted lesions.[9-11] In those experiments behavioral tests of hearing were used which, therefore, necessitated a postoperative recovery period. The lesions in those ears were consistently more widespread than was anticipated. This indicated that degenerative changes had spread out from the point of injury during the recovery period.

When the cortical test of auditory function was developed the opportunity was afforded of performing a test immediately after creating a lesion in the cochlea.[7] We believed this would allow experiments with smaller cochlear lesions than heretofore possible and provide additional information on the tuning (frequency analyzing power) of the cochlea.

METHOD

Healthy young adult cats were used in this experiment. An initial anesthetic dose of pentobarbital (Nembutal®) sodium was administered intraperitoneally. Since the duration of each experiment was from 10 to 20 hours, supplementary doses of dilute nembutal were administered through a canula in the femoral vein. Thus the depth of anesthesia was maintained at a constant level to control the amplitude of the base line electrical activity of the cortex. Rectal temperature was maintained between 37° and 39° C. by means of an electric heating pad placed beneath the animal.

The function of one ear was destroyed by entering the auditory bulla and inserting a metal probe through the round window so as to completely macerate the cochlea. The auricle of the opposite ear was amputated and a plastic coupler was sutured into the external auditory canal. This permitted the sound source to be maintained at a constant distance from the eardrum throughout the experiment. The contralateral auditory cortex was exposed and bathed with mineral oil warmed to the animal's body temperature.

At this stage, the first of a series of cortical tests of auditory function was performed (Fig. 1, top). The auditory cortex was covered with small patches of filter paper soaked in a saturated solution of strychnine sulfate. Monopolar recording was done at each patch in turn. The cortical response to sound stimuli introduced into the experimental ear was monitored on a cathode ray oscilloscope and a loud speaker. The criterion of cortical reponse was any constant deflection on the oscilloscope which occurred at a constant latency following the automatically keyed stimulus. The criterion

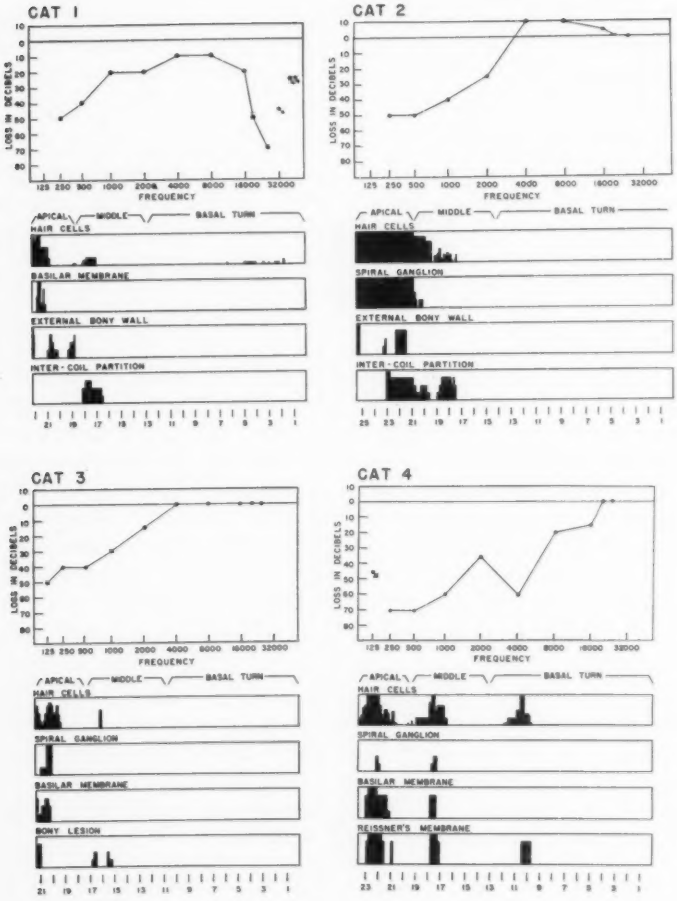

Fig. 2.—Cortical threshold tests and cochlear charts for four animals with apical lesions of the cochlea. The threshold curves show loss of sensitivity in decibels between the pre- and post-injury tests. The black filling in the cochlear charts is an estimation of degree of injury for the various elements. The scale at the bottom of each chart indicates distance in mm from the basal end of the cochlea.

differed from that used by Hind and Schuknecht[7] in that we did not require a full strychnine spike as a criterion of response. Otherwise our technique was similar.

The sound stimuli consisted of pure tones generated by an audio oscillator and keyed by an electronic switch at the rate of 1 per second. The tone pulses had a total duration of approximately 135 msecs and a rise time of 10 msecs. (For frequencies above 250 cycles, the output of the electronic switch was fed through a high pass filter to reduce keying transients.) The sound source was a permoflux PDR-10s earphone which was connected to the plastic coupler by a short length of flexible plastic tubing.

The minimum stimulus intensity necessary to evoke a cortical response was determined for frequencies an octave or less apart, from 125 to 50,000 cycles. Preliminary experiments were performed on a series of about 30 animals in order to develop the technique for cortical recording and ear surgery. An example of the difficulties encountered was the discovery that creating a small opening in the auditory bulla resulted in a significant threshold loss for the high frequencies. Immediate sealing of the opening with dental cement did not eliminate this loss. Cat 1 is an example of such an experiment in which an apical lesion in the cochlea, while creating a low-tone loss, also showed a severe high frequency loss (Fig. 2). In order to study the relationship of inner ear pathology to the threshold tests, it was essential to prevent any complicating sound conduction lesions. This complication was minimized in subsequent experiments by recording baseline thresholds immediately prior to creating the cochlear injury; i.e., after completion of all surgery including thinning of the cochlear bone. In all experiments, several threshold curves were taken over a period of several hours before creating the cochlear lesion in order to make certain that constant conditions were maintained throughout the experiment with regard to the sound source, the physiological state of the cortex, and the response of the middle ear structures.

A selected region of the bony cochlear wall was thinned with a dental drill until the scala tympani and scala vestibuli could be visualized as light-absorbing regions with the spiral ligament as a white line between them. This thinning was continued until the remaining bone was only 20 to 30 micra in thickness (see Fig. 9, top). At this stage one of two procedures was followed. For some animals a fine

TABLE 1.

STRUCTURE	PERCENTAGE FIGURE INDICATING ESTIMATED MAGNITUDE OF INJURY
	Rated as percentage of structure showing degeneration or displacement
Stria Vascularis	+ = 25%
Spiral Ligament	++ = 50%
Supporting Cells	+++ = 75%
Basilar Membrane	++++ = 100%
	Displacement not rated as abnormal
Reissner's Membrane	+++ = 75%
Tectorial Membrane	++++ = 100%
	+ = Linear Fracture = 25%
External Bony Wall	++ = Fracture displacement = 50%
Inter-coil Partition	+++ = Comminuted Fracture = 75%
	++++ = Missing = 100%
	Estimated percentage of fibres severed
Spiral Ganglion	0 to 100 in 25% steps
	0 = Normal
Hair Cells	◉ = Slight Damage = 33%
	• = Severe Damage = 66%
	+ = Missing = 100%

needle was introduced through the thinned cochlear wall into the spiral ligament. For the others a spark or a heating effect produced by a radio-frequency current from an electrocautery unit was applied to the bone over the spiral ligament without entering the cochlear duct. Usually about 15 minutes elapsed from the moment of creating the cochlear lesion to the completion of the cortical test and another 30 minutes to the completion of intra-vital perfusion with Heidenhain-Susa solution.

Graphic reconstructions of the cochleae were made[6, 8] and the pathological findings were entered in tables. An example is shown in Figure 1. The criteria for the degree of pathological change are shown in Table 1. The pathological findings and the curves of threshold loss were plotted on parallel and equal length coordinates using the anatomical frequency scale. The scale is based on the findings in previous frequency localization experiments. Frequencies are located on the abscissa of the audiogram in accordance with their hypothesized spatial distribution along the cochlear duct. The cochleae vary in length; however, in each case the frequency 32,000 cps is placed 9 per cent of the distance from the basal end, 16,000 cps at 21.3 per cent of the distance, etc. The development of the anatomical frequency scale for the cat is described in detail elsewhere.[8]

RESULTS: The animals can be grouped into those having lesions in either the apex, the middle region of the cochlea or the basal coil. Protocols for each animal follow. Charts for these animals appear in Figures 2, 3, 5, 7 and 8.

APICAL TURN LESIONS

Cat 1. In this animal the preoperative thresholds were measured before the bulla was opened. A needle introduced into the apical turn made a relatively large opening in the external bony wall and passed through the inter-coil partition into the middle turn. There were two distinct threshold losses; one for low tones and the other for high tones. The high frequency loss is typical of that which results from entering the auditory bulla and middle ear without visible injury to the eardrum, ossicles, or round window membrane and before creating an inner ear lesion. This problem was minimized in subsequent experiments by utilizing extremely careful technique; for example, not allowing an instrument or cotton to touch the drum, preventing a drop of fluid or blood from lodging on the drum, etc.

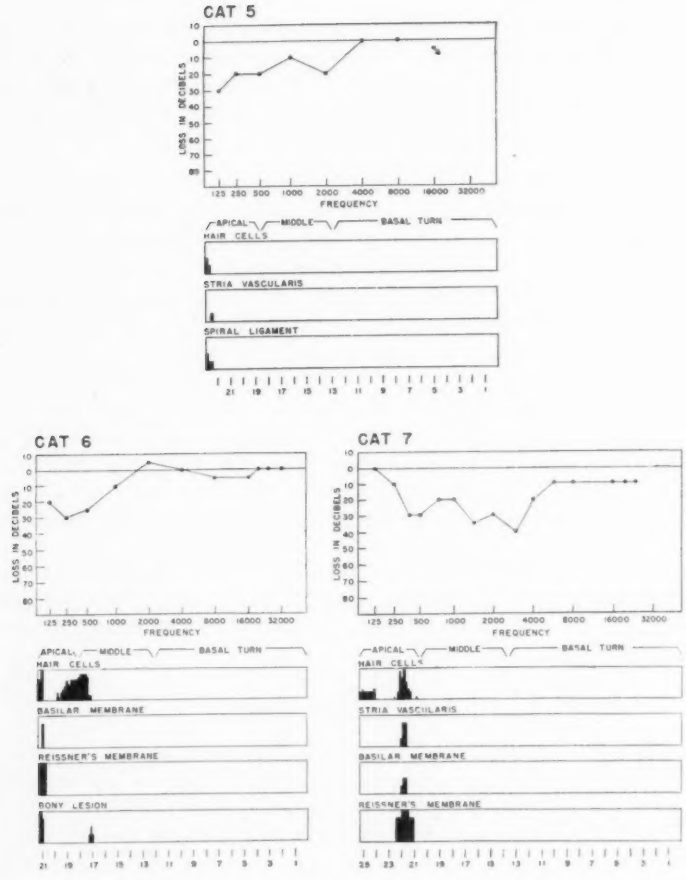

Fig. 3.—Results of injury to the apex of the cochlea of three cat ears.

Also, the base line threshold tests were taken after all surgery, including thinning of the bone, was completed.

Histological study disclosed that the lesion was most severe in the extreme apical region where all structures of the organ of Corti were missing or degenerated. The middle turn lesion corresponding to the break in the inter-coil partition showed only slight changes in the hair cells whose nuclei were pyknotic.

Cat 2. The lesion was made by creating an opening into the apex with a small burr and introducing a needle. Cortical tests gave no response at 125 cps when delivered at maximum intensity. There was a 50 db loss for 250 and 500 cps and above that progressive improvement to 4000 cps where the threshold was normal. The opening into the cochlea was sealed with dental cement without altering thresholds.

Histological examination disclosed complete disruption of all structures of the cochlear duct in the apical 3½ mm of the cochlea. Nerve fibers were completely severed at 21 mm thus preventing innervation of hair cells apical to the 21 mm point. The inter-coil partition was broken through over an extensive area of the apical and middle turns.

Cat 3. In this animal the needle was introduced at the apex and continued into the middle turn. There was a threshold loss of 50 db for 125 cps and above that thresholds progressively improved to normal at 4000 cps.

Histological study revealed damage to be most extensive in the apical 1½ mm of the cochlea (Fig. 4, top). In this area, the basilar membrane was torn, nerve fibers were severed, the tectorial membrane was torn and Reissner's membrane was torn or missing. Hair cells showed damage in the apical 2 mm. In the middle turn, Reissner's membrane and the tectorial membrane were torn and some hair damage was present over a very small area (Fig. 4, bottom).

Cat 4. The needle was introduced at the apex and continued deeply into the cochlea producing three distinct lesions. There was a widespread threshold loss which was worse for the low frequencies. There was a second peak loss at 4000 cps. Histological examination revealed three distinct lesions, one in each turn. The lesions were progressively less severe from apical to basal turn.

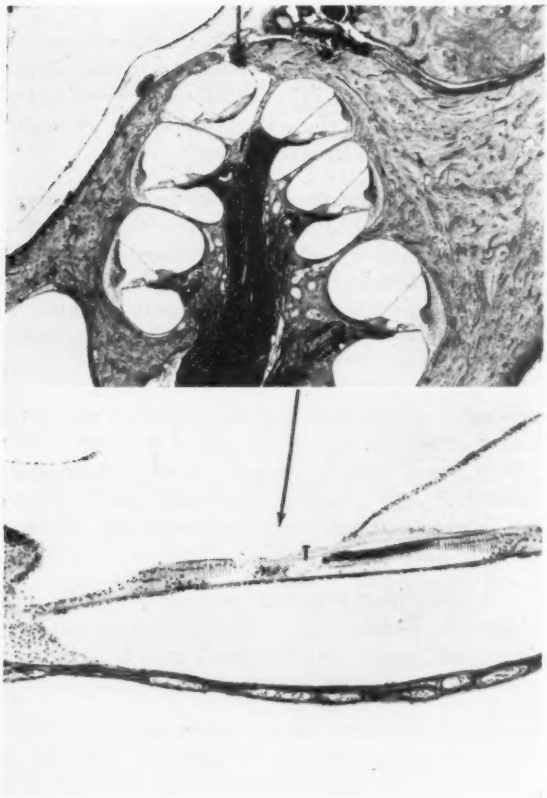

Fig. 4.—Top: Mid-modiolar section of the cochlea of Cat 3, showing the point of entry of the needle into the apex. Bottom: From the 16 mm region of Cat 3. The needle which was introduced into the apex of the cochlea passed through the bony partition into second turn. The point of the needle passed through Reissner's membrane in the direction indicated by the arrow and depressed the tectorial membrane (T) so as to crush the underlying outer hair cells. (See cochlear chart Cat 3)

Cat 5. Bone was thinned over the spiral ligament of the apical turn. Electrocautery was applied so as to create a spark and a local heating effect. The external bony wall was not broken. The threshold loss was relatively flat for frequencies below 4000 cps and reached a maximum of 30 db for 125 cps.

At the point of injury the spiral ligament was detached from the bone and showed cytolytic changes. Cytolytic changes were also present in the stria vascularis and hair cells. All damage was limited to the apical tip of the cochlea and covered an area of less than 1 mm.

Cat 6. A needle was introduced into the cochlear duct at the extreme apical end. There were threshold losses for frequencies below 1000 cps with a maximum loss of 30 db at 250 cps.

Histological examination revealed that the needle penetrated the basilar membrane at the apex and broke through the inter-coil partition into the scala vestibuli of the middle turn. There was complete loss of hair cells and Reissner's membrane at the point of entry and various degrees of degeneration of hair cells in a 3 mm area near the point where the inter-coil partition was broken through.

Cat 7. The bone was thinned over the apical turn until the outer bony wall was broken through at one point. No leakage of fluid was seen. Electrocautery was applied at this point. There was a rather flat loss of 20 to 40 db for frequencies from 375 to 4,000 cps.

Histological examination revealed degeneration of the organ of Corti in a ½ mm area at the point of application of the cautery. The spiral ligament showed cytolysis and the stria vascularis was torn and degenerated in this area. Reissner's membrane was ruptured over a 1½ mm area. The hair cells were missing and in various stages of degeneration over a 1 mm area. The hair cells in the apical 1½ mm of the cochlea also showed slight pyknotic changes.

MIDDLE TURN LESIONS

Cat 8. Electrocautery current was applied to the spiral ligament in the middle turn. The first threshold curve taken immediately after the lesion was made, showed a widespread threshold loss. A peak loss of 50 db was noted at 750 to 1000 cps. A second measurement made 45 minutes later showed a flattening of the curve and a greater loss for frequencies above 1000 cps.

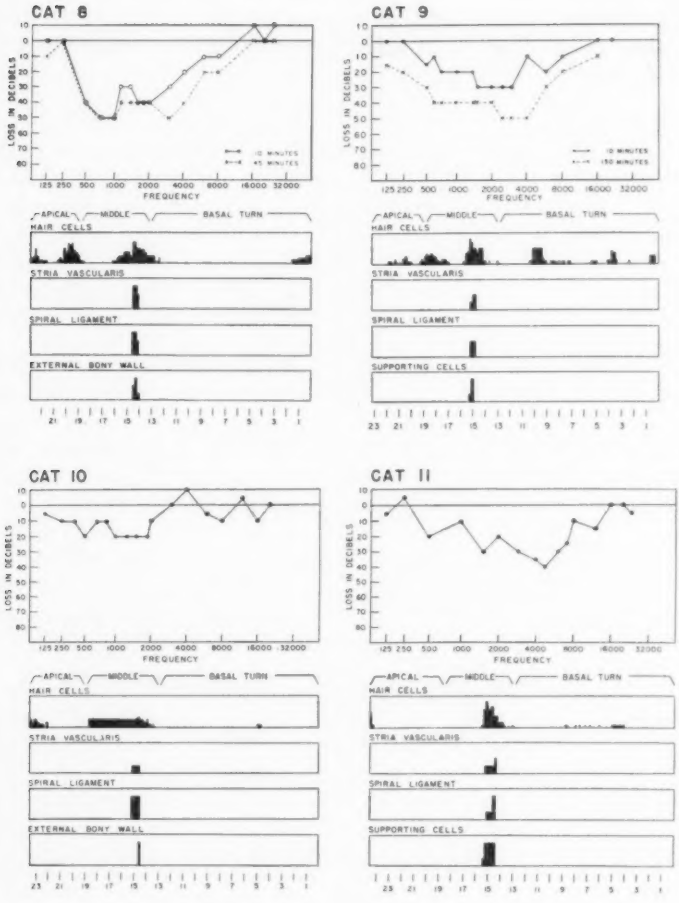

Fig. 5.—Results of experimental damage to middle coil (15 mm region) of 4 cat ears.

Histological examination showed the external bony wall was broken through in the 14½ mm region. Severe degenerative changes were present in the spiral ligament and in the stria vascularis in that region (Fig. 6, top). Hair cells were damaged in the area of injury between 13 and 16 mm and in the 19 to 21 mm area. Slight cytological changes could be seen also at the ends of the cochlea.

Cat 9. Electrocautery current was applied to previously thinned bone of the middle cochlear turn until the bone could be seen to turn white at the point of application. The first postoperative threshold curve showed a relatively flat loss of 20 to 30 db for frequencies between 500 and 4000 cps. A second threshold curve 150 minutes after the injury showed a further loss for all frequencies, although the losses were still greater in the middle range.

Histological study disclosed damage to the stria vascularis, spiral ligament and supporting cells of the organ of Corti in the 15 mm area. Hair cell changes were most severe in the area of injury but were also present at irregular intervals throughout the cochlea.

Cat 10. After opening the auditory bulla in this animal a small perforation was seen in the tympanic membrane. A small piece of gelfoam was placed in the defect. The first threshold curve was taken at this stage. The bony wall of the cochlea was thinned down over the middle turn until the drill cracked the wall and displaced the spiral ligament (Fig. 6, bottom). The threshold change was a flat loss of 20 db between 500 and 2000 cps.

Histological examination disclosed a displacement of the spiral ligament in the 15 mm area at the point of injury. Slight changes in the hair cells were seen throughout the middle turn and also in the last 2 mm at the apex.

Cat 11. Electrocautery was applied to thinned bony wall over the middle turn. A relatively flat loss of 20 to 40 db resulted for frequencies from 500 to 8000 cps. A peak loss of 40 db occurred at 5000 cps.

Histological study was complicated by a post-mortem linear fracture through the cochlea incurred in removing the temporal bone from the skull after perfusion. This resulted in some structural changes and may have introduced a slight error in computation of cochlear length. Cytological changes due to cautery were seen in

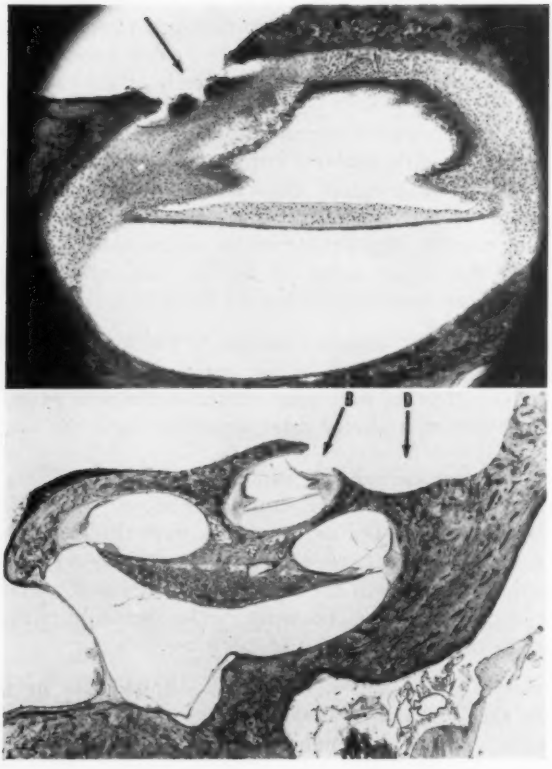

Fig. 6.—Top: Electrocautery was applied to the previously thinned bone in the 14.3 mm region of Cat 8. The underlying spiral ligament and stria vascularis show cytological changes verying from slight concentration of nuclear chromatin to complete dissolution of cellular structure. Bottom: From the 14.5 mm region of Cat 10. The drill created a saucer-shaped defect (D) to adequately expose the middle turn. The bony wall was opened at (B) depressing the spiral ligament but not opening the cochlear duct.

the spiral ligament, stria vascularis, supporting cells, and external bony wall in the 15 mm area at the point of injury. Hair cell damage was most marked between 14 and 16 mm (Fig. 10, bottom). Slight hair cell changes could also be seen at the extreme apex and in the basal turn.

BASAL TURN LESIONS

Cat 12. Electrocautery was applied to thinned cochlear wall over the spiral ligament in the middle of the basal turn. This resulted in a remarkably restricted high tone loss. There was a maximum loss of 60 db at 15,000 cps. Measurement at mid-octave frequencies showed the curve returned to normal by 11,000 cps in one direction and was near normal at 18,000 cps in the other direction. There were pyknotic hair cell nuclei between 3 and 5½ mm (Fig. 9, bottom). The spiral ligament showed cytolytic changes, typical of our cautery lesions, in the 5 mm area. The stria vascularis was displaced from the spiral ligament in the same region. Reissner's membrane was torn or missing between the 1 and 4 mm points.

Cat 13. Cautery was applied to the thinned bone over the spiral ligament in the basal turn. The resulting threshold losses were comparatively small. The peak loss was only 30 db for the frequencies between 20,000 and 24,000 cps.

Histological study revealed damage to the spiral ligament and stria vascularis in the 4 to 5 mm area (Fig. 9, top). Hair cell changes in the area of the lesion were slight. Hair cell changes were found at the basal end and in the 10 to 12 mm region. Reissner's membrane was torn or missing in the 4½ to 8 mm region.

Cat 14. The cautery current was applied to the thinned cochlear wall in the basal turn. The peak threshold loss was 55 db at 15,000 cps. The same pathological changes existed in the stria vascularis and spiral ligament as was noted in the cochleae of Cats 12 and 13. The hair cell changes were very slight at the point of injury but definitely present in the 1 to 3 mm region and also at the extreme apex.

Cat 15. The cautery lesion in this ear was made in the basal turn. The threshold curve showed some loss for all frequencies above 12,000 cps with a peak loss of 70 db for 20,000 cps. Sensitivity improved regularly in both directions from that maximum.

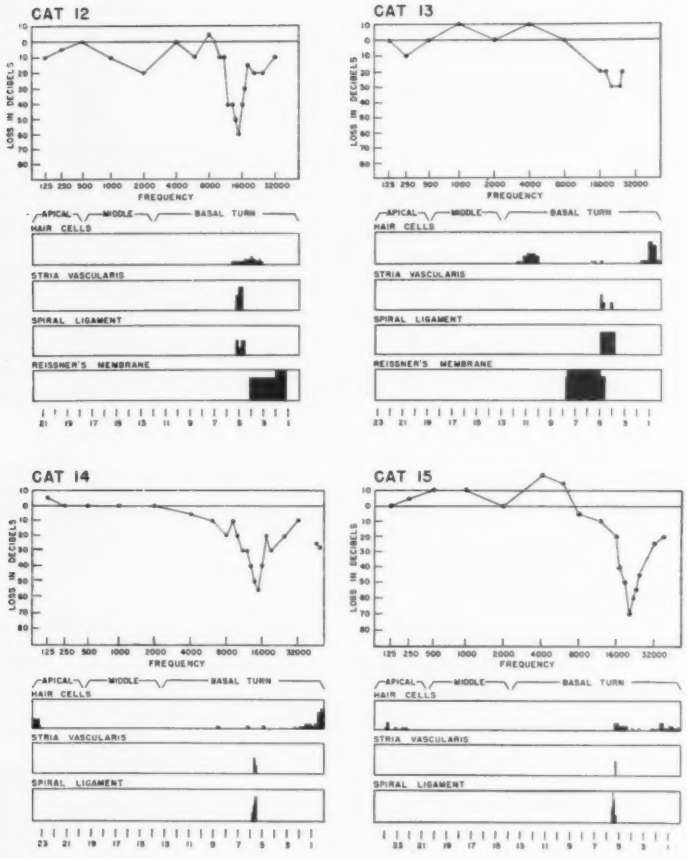

Fig. 7.—Charts showing threshold losses and visible cochlear changes in four animals receiving experimental lesions of the basal coil.

There was localized damage to the spiral ligament, stria vascularis, and supporting cells at 5½ mm. Slight hair cell changes could be seen in the first 6 mm and also in the apical turn.

Cat 16. After thinning the bone over the basal turn a needle was introduced through the spiral ligament into the cochlear duct. Immediately after the lesion was made there was a peak loss of 50 db for frequencies from 14,000 to 16,000 cps. There was gradual improvement for frequencies below 14,000 cps and thresholds were normal for frequencies below 4000 cps. A second threshold test taken 110 minutes later paralleled the first curve except that there was a greater loss at all frequencies. The maximum loss was still at 16,000 cps but the greatest deviations from the first curve were for 4000 and 8000 cps.

There was damage to the spiral ligament, basilar membrane and stria vascularis in the 5 mm region. There were some hair cell changes at the point of injury although slightly more hair cell damage occurred at the extreme apical and basal ends of the cochlea. The hair cell changes in the area of the injury consisted primarily of swelling of the nucleus and loss of staining characteristics, while elsewhere in the ear the main change was pyknosis of hair cell nuclei.

Cat 17. In this animal the bulla was opened and thresholds were measured. Then the bone over the basal turn was thinned until a small break occurred over the spiral ligament. A small amount of clear fluid exuded from this fracture. A threshold curve was taken. Sealing this defect with dental cement did not change the thresholds. The intravital perfusion was unsuccessful and the ear was removed from the skull and immersed in fixative.

There was a peak threshold loss of 80 db for 14,000 cps. The loss at 25,000 cps was 60 db and frequencies above 27,000 cps gave no response at maximum intensity. Frequencies below 6000 cps gave normal responses. There was disruption of the spiral ligament, stria vascularis and supporting cells in the area of injury at 5 mm. Hair cell damage was diffuse throughout the cochlea. These diffuse changes probably were caused by post-mortem degeneration as the result of unsuccessful arterial perfusion.

Cat 18. A sharpened needle was introduced through the round window into the cochlear duct. A peak loss of 40 db occurred at

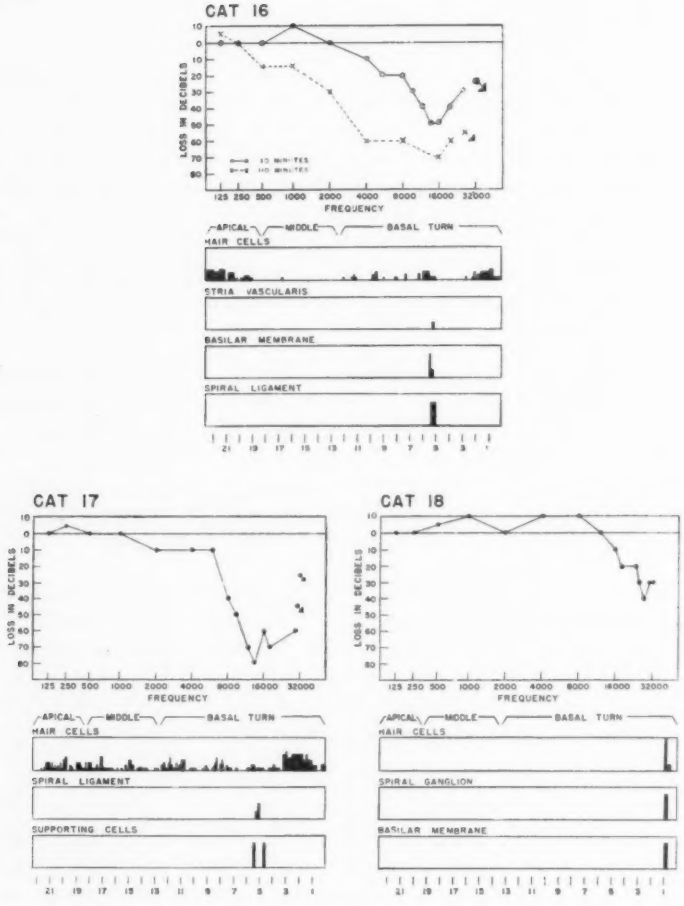

Fig. 8.—Results from basal lesions in 3 animals.

28,000 cps. The loss at 18,000 cps was 20 db and thresholds were normal for frequencies below 16,000 cps.

Histological examination revealed the needle entered the basilar membrane in the 1 mm region and severed fibers of the spiral ganglia at the point of entry. Hair cells were missing in the same area.

DISCUSSION

After preparation and preliminary testing the sequence for each animal consisted of performing the following procedures in rapid order: 1) creation of a small cochlear lesion, 2) performing a test of auditory function and, 3) performing intravital arterial perfusion. Ordinarily these procedures were accomplished in a time span of 45 minutes; therefore, we were able to minimize the spreading degenerative change in the sense organ which is characteristic of longer experiments.

To accomplish our purpose it was necessary to use perfusion and histological technique which preserved the sense organ with the least possible artifact, and to develop criteria for rating slight cytological and structural changes. See Figure 10 (top) for a typical normal organ of Corti in these experiments.

In cautery lesions hair cell changes were noted which deviated from the rest of the ear in that the nuclei were pyknotic and sometimes crenated. Some shrinking of the cytoplasm and increased eosinophilic staining properties were also noted in such cells (Fig. 9, bottom). Since such changes also occur when the perfusion technique is poor, each ear to an extent provided a standard for itself in that the hair cells in the area of lesion could be compared with the hair cells in the rest of the ear. The ear of Cat 17 was prepared by postmortem immersion in fixative instead of intravital perfusion. This was the only ear with diffuse hair cell changes and probably represents fixation artifact (see Fig. 8).

Certain types of changes in the hair cells were easily recognized as the effects of injury. These changes took various forms such as severe swelling of both cytoplasm and nucleus, decrease in the uptake of basic dyes by the nucleus, and nuclear fragmentation (Fig. 10, bottom). At the center of the lesion hair cells were often completely missing. Such changes were more common when injury was produced with a needle.

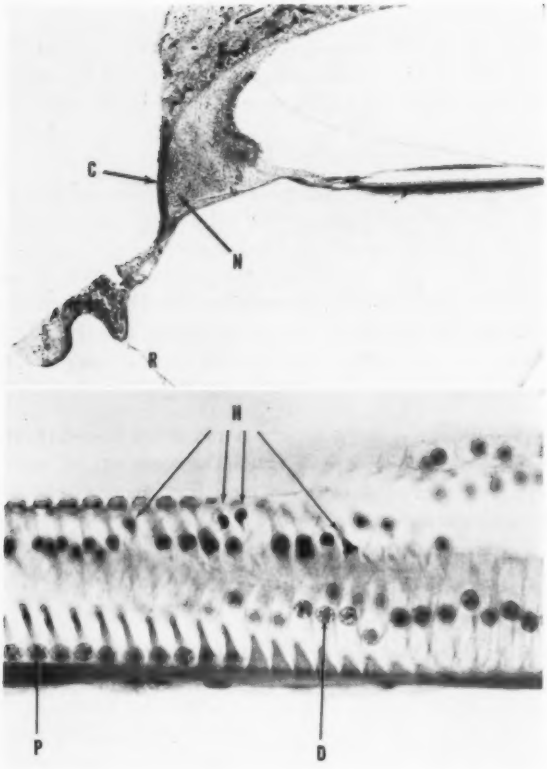

Fig. 9.—Top: From the 4.5 mm region of Cat 13. With a dental drill the bony cochlear wall was thinned. Electrocautery was then applied at (C). The underlying bone stained darkly with hematoxylin. The adjacent cells of the spiral ligament at (N) show nuclear crenation, fragmentation and dissolution. (R) is the round window membrane. Bottom: (H) indicates four degenerating outer hair cells in the 4.9 mm region of Cat 12, damaged by electrocautery. The nuclear chromatin is condensed, the nuclear outline is irregular and the cell outline is vague. The abnormal nuclei are displaced toward the top of 3 cells and to the bottom of one. The adjacent cells are normal outer hair cells but, of course, some are not in exact focus. (P) are the outer pillar cell nuclei and (D) are outer Deiter's cell nuclei.

Changes in other structures of the cochlear duct were rated as pathological only when we were quite certain they were ante-mortem. For example, Reissner's and the tectorial membrane were rated as pathological only if torn or missing.

In general, apical lesions produced low frequency losses; middle turn lesions produced middle frequency losses; and basal lesions produced high frequency losses. When relating threshold losses to the location of cochlear injury in the charts it should be remembered that the frequencies are plotted on the anatomical frequency scale. On this scale, the frequency spectrum is arranged in accordance with the predicted spatial distribution along the cochlear duct. Plotted on this basis a poor correlation was noted between threshold loss and location of injury only for Cats 7, 8, 9 and 11 (Figs. 3 and 5). In these ears, the frequency for which the maximum threshold loss was obtained was higher than would be predicted. A number of explanations for this might be considered. First, the data on which the anatomical frequency scale is based is least extensive with regard to the middle frequencies.[8] The anatomical frequency scale may be in error in this range, and the points of maximum excitation for these frequencies may actually lie closer to the apex as indicated by this experiment.

Secondly, this phenomenon reminds one of the finding in stimulation deafness experiments that maximum hearing losses tend to occur at frequencies one-half to one octave above the stimulating tone.[2]

Thirdly, the relative flatness of the curves of threshold loss for the middle turn lesions suggests that we use caution in making inferences regarding localization for the middle frequencies. For example, it may be noted in the chart for Cat 11 that the maximum threshold loss at 5000 cps is only 10 db greater than that for nearby frequencies. Since this is within experimental error it is not possible to speak of a peak threshold loss in this ear that is any narrower than two octaves.

For the apical and middle turn lesions (Cats 1 through 11) both the degree of threshold loss and the band width of frequencies for which there is a threshold loss are directly related to the severity of the underlying pathology. This relationship is not evident for basal lesions.

We were successful in creating remarkably restricted threshold losses for high frequencies by creating small basal turn lesions. Note

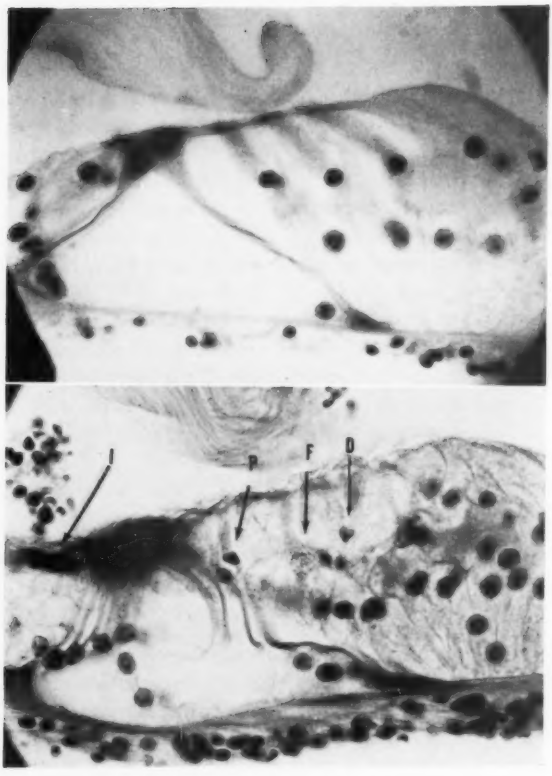

Fig. 10.—Top: Normal organ of Corti (Cat 7, 17.4 mm). The cytology as shown was considered normal for this experiment. Bottom: Damaged by electrocautery (Cat 11, 15.2 mm). There is slight condensation of chromatin in inner hair cells. The inner hair cells are also displaced upward (I). The outer hair cell nuclei show pyknosis (P), fragmentation (F), and dissolution (D).

that a 60 db threshold loss for 15,000 cps for Cat 12 is consistent with normal sensitivity for frequencies less than half an octave in either direction. For all the basal turn lesions the band width of frequencies affected was between one and two octaves. Also for a number of animals with high frequency losses we were able to demonstrate near normal thresholds for frequencies above the frequency for which there was maximum threshold loss (Cats 12, 14, 15). It is of interest to note that threshold losses were greatest for 28,000 cps in Cat 18 and for 20,000 cps in Cats 13 and 15. To our knowledge, this is the first information available on localization for such high frequencies. It was unfortunate that the high frequency loss which occurred when the bulla was opened made impossible a more thorough investigation of frequencies up to 50,000 cps in the cat.

Lesions in the apical turn also resulted in more restricted losses for low tones than was previously possible.[9] Thus, in Cat 3, a threshold loss of 50 db at 125 cps is consistent with normal sensitivity for frequencies above 2000 cps. Similarly, a 50 db loss at 250 and 500 cps in Cat 2 is consistent with normal sensitivity for frequencies above 4000 cps and in Cat 6, a 30 db loss at 250 cps was found to be consistent with normal sensitivity for frequencies above 1000 cps. These findings clearly show that while the tuning is broader for low tones we can definitely speak of specific areas of response for low tones. This conclusion is in agreement with previous findings by Schuknecht and Neff[9] and Gross.[5]

Tasaki[12] in a recent experiment found single fibers of the auditory nerve which responded to frequencies in the range from 500 to 9000 cps. This is not necessarily inconsistent with our results since his stimuli were delivered at relatively high supra-threshold intensities.

The findings with regard to our middle turn lesions (at 15 mm in our experiments) supplement previous findings in the cat. Lesions in the 15 mm region caused threshold losses over several octaves even when the lesion was moderate in severity. This is probably related to the fact that middle and apical turn lesions seemed more difficult to produce than basal turn lesions. In some ears it was necessary to introduce the needle more deeply on a second attempt or to use stronger electrical currents before any measurable threshold changes could be demonstrated. On the other hand, it was easy to create threshold losses when making basal lesions and we felt that more

restricted threshold changes might have been produced could we have refined even further our method of making restricted lesions. It seems reasonable to assume that this difference between the basal lesions and lesions in the other two turns is another reflection of the greater sharpness of tuning for higher frequencies.

Our findings are consistent with the concept that sharpness of tuning increases as frequency increases. This observation is similar to that of Galambos and Davis[4] for second-order neurons. They found that neurons which were sensitive to high frequencies were more sharply tuned than neurons which were sensitive to low frequencies.

The cochlear charts of these 18 ears reveal two general kinds of information; 1) the location of application of injury, as evidenced by changes in the bony wall, spiral ligament, stria vascularis and basilar membrane, and 2) the magnitude of the sensory lesion, as evidenced by the severity and distribution of cytological change in hair cells. In most charts the peaks for the threshold losses correlate well with the points of application of injury which lends credence to the anatomical frequency scale. In regard to sensory cells, it should be understood that the charts present morphological and not functional evaluations. For most animals the band width of frequencies for which there was a threshold loss was greater than we would have predicted from the purely morphological changes found in the sense organ. This suggests that for the hair cells the zone of functional loss had spread beyond the borders of the zone of morphological change. This is consistent with the findings in a previous experiment in which one of us (H. F. S.) showed that stimulation deafness can exist without demonstrable morphological changes in the inner ear using standard histological techniques.[10]

It might be of interest to consider the ossible causes for hair cell injury in this experiment. In the needle lesions there was direct mechanical injury to the hair cells and surrounding elements. In many ears there were structural changes which must have altered fluid and electrical barriers of the inner ear. Tearing of Reissner's membrane would cause a mixing of fluids of the cochlear duct and the scala vestibuli. Similarly, breaking through the inter-coil partition would cause a mixing of the fluids of the scala tympani of one turn with the scala vestibuli of the adjacent turn. We found in several ears that hair cell damage occurred in the second turn when

the only structural change in that turn was a fracture of the intercoil partition.

In the cautery lesions, there was certainly a local heating effect at the point where the cautery was applied. It is quite possible that heating caused the greatest damage in middle turn lesions because of the high intensities and long application of current. Fernandez, *et al*[3] using high frequency currents to injure the cochlea of the guinea pig believed that impairment in the microphonic response was due to heating or the formation of a bubble. Bubbles may have occurred in two of our ears (Cats 12 and 13) in which Reissner's membrane was torn on the side opposite to the application of the cautery. Finally, damage to the stria vascularis in the cautery lesions may have caused local nutritional and chemical changes in the endolymph secondary to local disturbance of circulation.

SUMMARY AND CONCLUSIONS

Small cochlear lesions were created by mechanical injury with fine needles or with controlled electrical current in the apical, middle and basal turn of the cat cochlea.

The cortical technique was used as a method of evaluating the function of the injured cochlea. The test proved reliable, had the advantage of being less time consuming than behavioral tests, and could be performed without injury to the various anatomical elements of the auditory system. The most important advantage of the cortical test in this experiment was that it could be performed within a few minutes following cochlear injury. Thus it was possible to make recordings and perfuse the animal before degenerative changes had spread within the cochlea. This provided us with a technique for more accurate study of the tuning or resolving power of the cochlea.

The procedure for each animal consisted of making a pre-injury cortical threshold test, creating the cochlear injury, performing a post-injury test, and performing intravital perfusion. The time lapse from creating the cochlear injury to perfusion was usually less than 45 minutes.

A detailed, quantitative study was made of inner ear pathology. The histological preparations were good enough to allow us to record slight pathological changes. Pathology was spatially and quantitatively recorded for the hair cells, spiral ganglion, stria vascularis,

basilar membrane, Reissner's membrane, spiral ligament, and the bony walls.

The results confirm previous concepts of an orderly, spatial distribution of frequencies within the cochlea. The sharpness of tuning is greater for high frequencies than low frequencies, which is consistent with the results of previous experiments.

Probably the most significant result was our ability to create more severe, and at the same time more restricted, threshold losses in all regions of the auditory spectrum than had hitherto been possible.

The method here used for testing auditory threshold involves the physiological response of the cochlea, auditory pathways, and cortex. We believe that the threshold curves represent the tuning capacity of the cochlea to the extent that we could test it. This seems reasonable in that the threshold losses reflect purely cochlear dysfunction and the action of the neural mechanisms above the cochlea were not altered.

Our success in creating more restricted threshold losses can be interpreted to mean that a greater burden for frequency analysis must be placed on a place principle of cochlear function than has been demonstrated previously.

The authors wish to thank Mr. George Orland and Dr. Joseph E. Hind for their assistance with the cortical recording, Mr. Robert Kimura for his assistance with the evaluation of the histopathology, and Mrs. Cindy Gillis for the histological preparations.

This work was done in the Research Laboratory of the Department of Otolaryngology of the University of Chicago Which is Under the Direction of Dr. John Lindsay.

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LIV

INNER EAR PATHOLOGY DUE TO MEASLES

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The importance of measles as a cause of deafness and hearing impairment has been demonstrated by statistical studies on deaf children.

On the basis of reports on acquired deaf-mutism published by various European authors before 1926, Lederer of Dresden[1] concluded that three to four per cent could be attributed to measles.

G. E. Shambaugh, Sr. et al[2] in 1928 reported on 3,120 cases in schools for the deaf in the Chicago area: 38 per cent were considered to have acquired deafness and of these, 97 cases (8.8 per cent) were due to measles. Seventy per cent of these 97 cases were due to inner ear damage unassociated with otitis media or meningitis with an abnormal response to vestibular tests in about half.

Macfarlan[3] in 1928 reported on 613 deaf children in Philadelphia. He found that 9.2 per cent of the acquired cases were due to measles, fourteen (25 per cent) of which gave no history of otitis media.

MacLeod Yearsley[4] in 1934 reviewed 4314 deaf children seen over a twenty-five year period in schools for the deaf in London, England. There were 2925 (69 per cent) cases of acquired deafness of which 281 (9.3 per cent) were considered to be caused by measles. On breaking down the 281 cases of measles, 174 had suppurative otitis media, 56 were called "catarrhal" and 51 were due to inner ear damage alone. Forty-five of the cases of inner ear damage were completely deafened.

From the Division of Otolaryngology of the University of Chicago.

Goodman[5] in 1949 published 343 cases in schools for the deaf; 181 were acquired and eight (4.4 per cent) of these were thought to be due to measles.

Simpson[6] in 1949 studied 100 cases of perceptive deafness seen during one year at the Royal Infirmary in Edinburgh. Two were caused by measles without otitis media. Bordley and Hardy[7] in 1951 reviewed 296 deaf children tested by the Psychogalvanic Skin Resistance Method. Of these cases 15 (5 per cent) were considerd to be due to measles.

Bordley[8] in 1952 analyzing 485 preschool deaf children concluded that 31 (6.4 per cent) were attributable to measles.

Kinney[9] in 1953 reported on 2995 children with impaired hearing. Of the cases of hearing loss of the perceptive type about 10 per cent were possibly due to measles.

Deafness or hearing impairment from measles may be brought about in several different ways. Congenital deafness may apparently be caused by measles during pregnancy. Packer[10] reported one case of partial deafness among 18 children of mothers with measles in pregnancy. Fox et al[11] found no deafness in seven such cases. Congenital deafness due to measles appears to be less common than that due to maternal rubella.

The suggestion was made by Bordley and Hardy[7] that immunization against measles during pregnancy was the possible etiology in two cases of congenital deafness.

The most common complication and the most common cause of hearing impairment due to measles has been suppurative otitis media. With appropriate antibiotic therapy complications due to an associated bacterial infection of the ears and respiratory tract should be a rare occurrence.

Deafness following measles meningo-encephalitis appears to be uncommon. In his review of the nervous complication of measles Ford[12] made no mention of deafness.

It is probable that the most frequent type of deafness caused by measles, since the use of antibiotic therapy, has been that due to the direct effect of the disease (virus) on the inner ear. This is referred to in the literature as a neurolabyrinthitis or an acoustic neuritis. Although this complication has been a relatively frequent

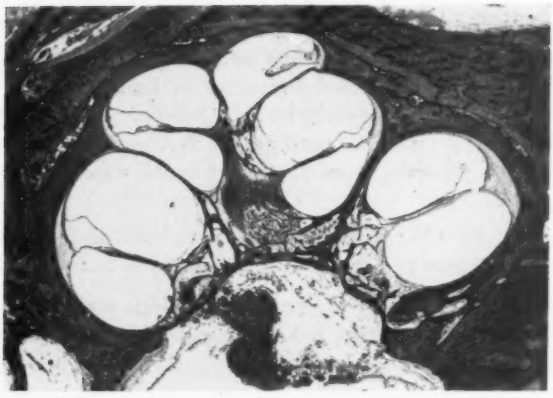

Fig. 1.—Mid-modiolar section of the right cochlea. The deformity of the tectorial membrane is recognizable in the upper coils. The degeneration of Corti's organ, the stria vascularis, the nerve fibers in Rosenthal's canal and the ganglion cells in the spiral ganglion of the basal coil can be seen at this magnification.

cause of deafness there have been few reports on the pathologic process.

Moos[13] in 1887 described the pathology in the inner ear in one case following measles. Invasion of the labyrinth by bacteria and pathologic changes characteristic of an early suppurative labyrinthitis were demonstrated in that case.

Nager[14] in 1917 presented a detailed report on the case of a six-year-old child with complete deafness following measles three years before. The ears showed fibrous tissue and new bone formation in the perilymphatic spaces of the vestibule and cochlea. The utricle, saccule and cochlear duct of the basal coil were dilated, while the upper two coils showed no hydrops. The stria vascularis and the organ of Corti showed marked atrophy in the basal coil, and less alteration in the upper two coils. The tectorial membrane was detached, rolled up and covered with flattened cells in the basal coil only. The peripheral nerve fibers and ganglion cells were degenerated in the basal coil.

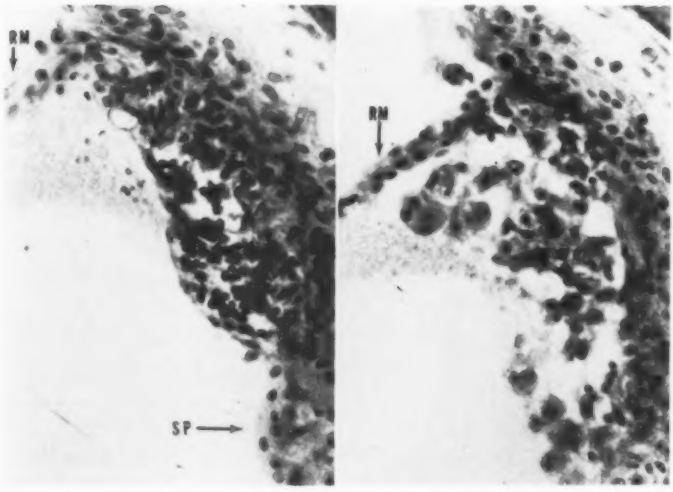

Fig. 2.—High magnification of the stria vascularis in the apical coil showing a localized focus of inflammation with infiltration by small lymphocytes and swelling of the epithelial cell layer. Some amorphous exudate overlies the focus. R. M. Reissner's membrane. S.P., Spiral prominence.

Fig. 3.—A high power section close to Figure 2 showing the degenerated stria covered by exudate, a few small lymphocytes and many large multinucleated cells.

These changes within the cochlear duct showed similarity to those to be described in this report. However, the proliferation of fibrous connective tissue and bone formation in the perilymphatic spaces was similar to that commonly seen in a healed serous labyrinthitis due to bacterial infection. This patient had survived a complicating meningitis from measles. In the absence of recorded spinal fluid findings the nature of the meningitis was not clear. However, the spontaneous recovery suggests that it may have been a measles meningo-encephalitis and that the inner ear changes were also the effect of the measles virus either as a meningogenic extension or concomitant involvement of the perilymphatic system.

Hagens[15] in 1937 gave a brief report on a fourteen year old patient who had been totally deaf following measles one year before

Fig. 4A.—Section through upper middle coil right ear. A small portion of the stria remains covered by exudate. The tectorial membrane and hair cells are degenerated. Supporting cells are fairly well preserved as well as the nerve fibers.

Fig. 4B.—Section through the upper basal coil showing complete loss of the stria vascularis and Corti's organ. The nerve fibers in Rosenthal's canal have been reduced in number. A remnant of the tectorial membrane is visible covered by flattened cells.

Fig. 4C.—Section through the lower basal coil showing complete disappearance of the stria vascularis and organ of Corti. The rupture of Reissner's membrane and the bulbar membrane is an artifact. Only a few nerve fibers remain.

death. The organ of Corti was absent in all coils and there was marked degeneration of the nerve and spiral ganglion. Abnormalities were also present in the vestibular sensory structures.

This case presented no evidence of a bacterial labyrinthitis and probably represented the end result of an uncomplicated so-called "acoustic neuritis."

In view of the scarcity of detailed information about the development of the pathologic process as it may affect the inner ear the case to be presented is of particular interest.

CASE REPORT

Eric, male child, aged 7 months—No. 71367.

This infant was referred to the University of Chicago Clinics from a foundling home on December 7, 1932 at the age of three months. A rash on the body was diagnosed as typical of measles. Bilateral suppurative otitis media developed with a perforation of the right tympanic membrane shortly after admission to the hospital. There was no sign of labyrinthitis. There is no information on record concerning auditory function. No details of the prenatal or natal history were available. The infant developed myocardial complications and a bronchopneumonia. On April 4, 1933, 3 cc of measles convalescent serum were given. Two blood transfusions were administered. Death occurred on April 24, 1933.

An autopsy was done on April 24, 1933 by Dr. Eleanor Humphreys. Post-mortem diagnosis was parenchymatous degeneration of the myocardium, liver and kidneys (toxemia associated with measles). Bilateral pulmonary hyperemia and edema with focal atelectasis. Right suppurative otitis media. Brain and meninges were normal. Both temporal bones were removed and sent to the Department of Otolaryngology for study. The bones were fixed in formalin and decalcified in the usual manner. They were sectioned at 20 microns and every tenth section was stained with hematoxylin and eosin.

RIGHT TEMPORAL BONE

Middle Ear: The tympanic membrane was distorted anteriorly and partly missing from the specimen. The ossicles appeared normal. The mucosa showed moderate inflammatory thickening in some areas but no exudate or pus was present.

Fig. 5.—Section through the saccular macula. The collapsed outer walls of the saccule can be seen overlying the macula and in one area there is a loose fibrous connective tissue attachment. The sensory cell layer shows degeneration.

Otic Capsule: The bony labyrinthine capsule appeared normal throughout.

Inner Ear: The membranous structures were fairly well preserved with relatively little evidence of postmortem degenerative changes (Fig. 1).

Perilymphatic Spaces: There were several limited areas in which the perilymph showed increased affinity for the stain. These were mainly in the scala tympani bordering on the basilar membrane. There were no other inflammatory signs and no proliferation of connective tissue.

Endolymphatic System: Cochlear Duct. Although there were some irregularities in both Reissner's membrane and the basilar membrane the volume of the endolymph in the scala media appeared to be normal.

Stria Vascularis: In the upper end of the basal coil only a few small round cells and a few giant cells remained in the position normally occupied by the stria. Further down in the basal coil none of the stria remained and the spiral prominence had also disappeared.

Fig. 6.—Section through upper part of the utricular macula and the crista ampullaris of the horizontal semicircular canal. The endolymph shows increased affinity for eosin. The otolithic membrane and the cupula are absent. The sensory epithelium has degenerated. On both side of the crista can be seen a proliferative mass which consists mainly of young fibrous connective tissue, small lymphocytes with the degenerated sensory epithelium beneath. The infiltration extends throughout the crista as well.

In the middle coil remnants of the stria were seen in the lower part increasing progressively towards the apex. In the apical coil the stria was present in all areas although reduced in extent and abnormal in appearance. Many areas showed varying degrees of infiltration with round cells with some exudate on the surface. In one localized area in the apical coil (Figs. 2 and 3) the stria had lost its form and consisted of a mass of swollen endothelial cells and some small round cells. Overlying this was an exudate in which were a few large cells some of them multinucleated. The capillaries were no longer visible in this section.

There was a moderate degree of increased staining of the endolymph in localized areas. There was a break in both Reissner's and the basilar membrane in the medial part of the basal coil apparently of artifact.

Tectorial Membrane: The tectorial membrane showed a degenerative change throughout. In the apical and middle coils (Fig. 4A)

it had been detached from the limbus spiralis and appeared as a deformed mass covered by flattened cells adjacent to Corti's organ in the region of the inner hair cell. In the basal coil (Figs. 4 B and 4 C) the only remnants of the tectorial membrane were a few flattened irregular cells.

Organ of Corti: There were progressive degenerative changes in Corti's organ from the apical coil downward. The degree of degeneration seemed to correspond to that seen in the stria vascularis. In the extreme apical region the supporting cells, pillar cells and Hensen's cells were well preserved but both the outer and inner hair cells show well marked degenerative changes (Fig. 4A). The degeneration increased progressively in the lower apical and middle coils. The pillar cells and supporting cells showed abnormalities progressing from above downward in the middle coil while in the upper basal coil the degeneration had progressed to the point where Corti's organ was entirely absent (Fig. 4B and 4C).

In the apical and middle coils the nerve fibers and ganglion cells appeared to be normal in number. In the lower middle and basal coils there was a progressive diminution of nerve fibers and ganglion cells from above downward (Fig. 4B and 4C).

Vestibular System: Perilymphatic spaces in the vestibule and semicircular canals showed a slight increase in the fine connective tissue trabeculae carrying blood vessels. The staining reaction was normal throughout and showed no other evidence of inflammatory reaction.

The endolymph in the utricle and semicircular canals stained pink with eosin throughout.

The Saccule: The walls had collapsed obliterating the cavity almost entirely (Fig. 5). The otolithic membrane had apparently been separated from the sensory cell layer and had been enveloped in the collapsed saccular wall which itself lay in irregular folds over the macula. The sensory cell layer showed moderate degenerative changes.

Loose connective tissue adhesions had formed between the collapsed walls of the saccule and the macula. The remnants of the endolymphatic space contained some fine pink-staining trabeculae and large detached cells with single or double nuclei.

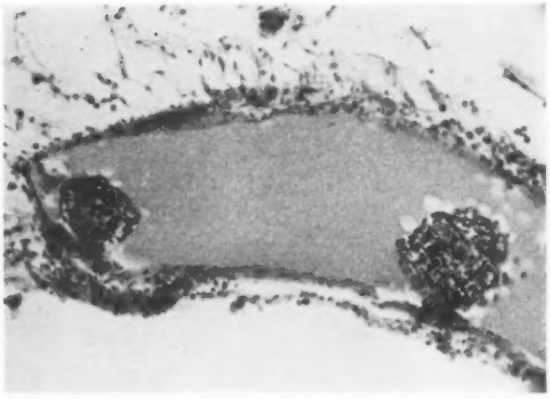

Fig. 7.—High power view of the lower part of the utricle showing two papillomatous lesions attached to local thickened areas of the wall. These are proliferative lesions containing both epithelial and mesenchymal elements as well as some multinucleated giant cells. These aggregates of cells probably represent focal lesions due to the measles virus similar to those occurring in the skin. The endolymph has increased affinity for the stain.

Utricle: The pink staining characteristic of the endolymph had apparently been limited to the utricle and semicircular canals by the utriculo-endolymphatic fold (Fig. 6). The macula showed moderate degeneration of the sensory cells. The otolithic membrane was missing. At three other points in the wall of the utricle there was a localized papillomatous cellular mass protruding from the lining epithelium (Fig. 7). These projected from a slightly thickened area of the utricular wall as masses of proliferated epithelial cells, some multinucleated, with some small round cells and a few leucocytes. These aggregates of cells were suggestive of a measles granulomata.

Semicircular Canals: The cupula was missing in all three canals. In the superior canal the sensory epithelium seemed to be fairly well preserved.

The crista of the posterior canal was fairly well preserved except for a localized area showing a chronic inflammatory reaction with breakdown of the epithelial layer and protrusion of swollen

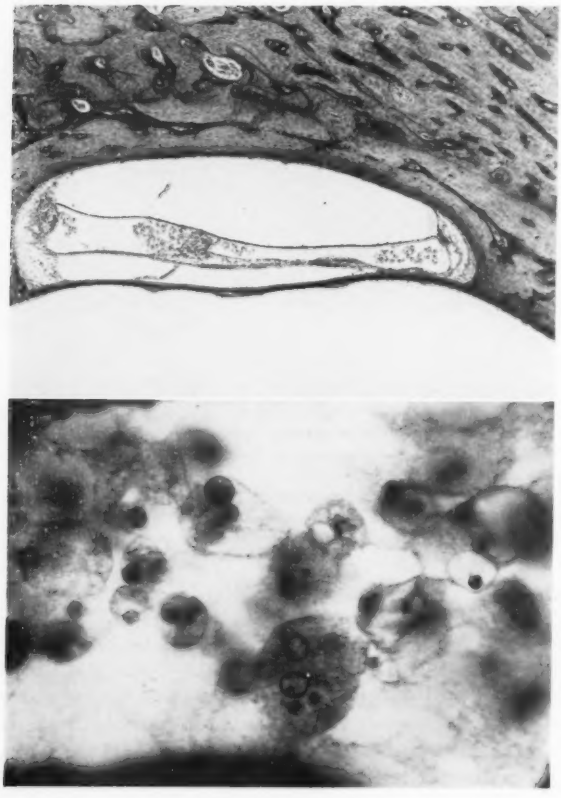

Fig. 8A.—Section through the apical coil of the left ear. An inflammatory focus is shown in the stria at the left with degeneration of the surface layer. Collections of loose cells are scattered through the endolymph.

Fig. 8B.—High power magnification (X950) of a group of the cells shown lying loosely in the endolymph in Fig. 8A.

epithelial-like cells. In the horizontal canal the crista ampullaris (Fig. 6) showed marked pathologic changes. Hair cells were no longer recognizable. Remnants of the sensory epithelium were present but overlying this were masses of proliferated tissue consisting of small round cells, young fibrous connective tissue, swollen endothelial cells, occasional leucocytes and multinucleated giant cells. The subepithelial part of the crista was infiltrated with small round cells with an apparent increase in fibrous connective tissue.

LEFT TEMPORAL BONE

The middle ear contained small collections of purulent exudate in some areas. The mucosa showed moderate inflammatory thickening and increased vascularity. The ossicles and tympanic membrane were in good condition.

The bony capsule was normal throughout.

Inner Ear: The membranous structures of the inner ear were fairly well preserved but distorted by air bubbles in the scala vestibuli and cisterna perilymphatica.

Cochlea: The perilymph showed a moderate increase in staining reaction throughout with a small amount of amorphous exudate in some areas. The scala media was flattened down towards the basilar membrane in the middle and upper basal coils due to a large air bubble in the scala vestibuli. The endolymph showed increased affinity for the stain and in the apical coil there were collections of large loose cells, many with two or more nuclei (Figs. 8A and 8B).

Stria vascularis: The stria vascularis was abnormal throughout. There were degenerative changes progressing in degree from the apex downward.

In the upper part of the basal coil the stria had disappeared entirely. In the apical turn in which it was damaged least the stria was infiltrated in some areas by small round cells. Degeneration of the surface epithelium had occurred in some localized areas, with amorphous debris and occasional loose cells overlying the surface (Fig. 8A and 8B).

In the lower part of the middle coil the stria had almost disappeared. The spiral prominence also became flattened out in lower middle and basal coils.

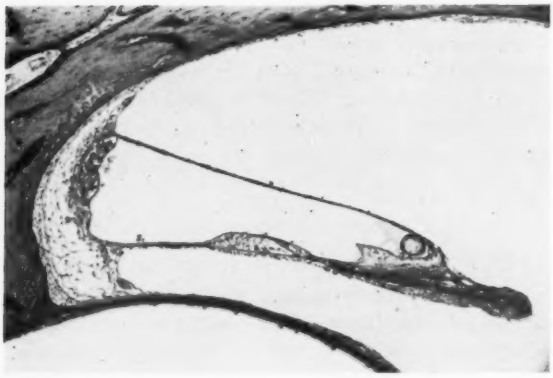

Fig. 9.—Section through the apical coil left ear showing the supporting structures of Corti's organ well preserved but the hair cells degenerated and the tectorial membrane detached, rolled into a ball and lying in the angle between Reissner's membrane and the osseous spiral lamina. The stria vascularis also shows a degenerative change.

Tectorial membrane: The tectorial membrane was degenerated throughout. In the apical region it was detached completely and appeared as a spherical mass covered by a single or double layer of flattened cells (Fig. 9) in the angle between Reissner's membrane and the limbus.

Lower down in the apical, middle and upper basal coils it lay as a deformed mass in the internal sulcus covered on its upper surface by a layer of cells, mostly flattened but in some areas cuboidal which extended from Henson's cells to the limbus, resting on the basilar membrane from which it was separated by an incomplete layer of flattened cells.

Corti's organ: In the upper part of the apical coil the organ of Corti showed degeneration of the outer and inner hair cells as well as detachment of the tectorial membrane. Hensen's cells, the cells of Claudius, and the pillar cells were present (Fig. 9). The supporting cells appeared to be undergoing degeneration.

Further down in the middle coil the supporting cells and pillars were absent, leaving only a low layer of Hensen's cells as the last remnant of Corti's organ.

Peripheral cochlear neuron: The nerve fibers and ganglion cells seemed about normal in the apical coil, but in the middle coil their number showed a progressive decrease. This decrease seemed to parallel the loss of supporting the pillar cells in Corti's organ. A few fibers and ganglion cells remained in the basal coil where all remnants of Corti's organ were absent.

Vestibule: There were air bubbles in the perilymphatic spaces of the vestibule, which had apparently ruptured the walls of the utricle below the macula and caused distortion. There were no proliferative changes in the perilymphatic or endolymphatic spaces and the staining characteristics appeared normal.

Saccule: The outer wall of the saccule was collapsed upon the macula, apparently the effect of the air bubble in the vestibule.

Utricle: The otolithic membrane was partly separated from the sensory epithelium. The hair cells were fairly well preserved with occasional vacuolated cells visible.

Semicircular Canals: The cupula was in normal position in the superior and horizontal canals. The sensory cells were mostly preserved but many clear spaces were present, apparently large vacuoles in degenerating cells.

COMMENT

The right ear showed degenerated changes affecting both the auditory and vestibular sense organs. The perilymphatic system was almost free from change.

The left ear showed degenerative changes in the structures within the cochlear duct which were similar to those on the right side. The collapse of the saccule was probably artifact, the result of compression by the air bubble. The utricle and semicircular canals showed fairly normal appearing sense organs with none of the evidences of inflammatory change seen on the right side.

The structures in the cochlear duct on both sides showed progressively greater degeneration from apex to base. In the basal coil (Fig. 1) only slight remnants of stria were seen and Corti's organ was absent. The tectorial membrane was mostly absent and Rosenthal's canal contained only a small fraction of the normal number of nerve fibers (Figs. 4B and 4C) and the ganglion cells were proportionately reduced. In the apical and upper middle coils where

part of the stria was still present as well as the supporting elements of Corti's organ the nerve fibers and ganglion cells appeared grossly normal in number (Fig. 1). The tectorial membrane was deformed, detached and displaced throughout. The hair cells were degenerated throughout.

There were areas in the remaining stria vascularis where a localized chronic inflammatory reaction was still active.

The degenerative changes in the vestibular system in the right ear appeared limited to certain areas. There were chronic proliferative changes localized within the cristas of the horizontal and posterior semicircular canals. These involved both mesenchymal and epithelial cells with breakdown of the epithelial cell layer. There was infiltration by round cells, a few leucocytes, proliferation of fibrous connective tissue and swollen epithelial cells, some of which were multinucleated.

DISCUSSION

The age of this patient precluded any clinical evaluation of function, but on the basis of the histopathology it is clear that auditory function was destroyed in both ears. Vestibular function was probably destroyed on the right side only.

There was no clinical sign of meningocephalitis in this case and no pathologic changes in either the meninges or the perilymphatic spaces. Therefore, the pathologic findings involving the structures within the endolymphatic system may be considered to have been the direct effect of the measles virus. Death occurred about three and one-half months after the acute stage of the measles, hence sufficient time had elapsed for complete degeneration of the receptor organ and peripheral neuron in the basal coil. The degeneration was progressively less advanced toward the apex and signs of inflammatory activity were still present. In the vestibular system on the right the process indicated a late stage with evidence of active inflammation still present.

The interpretation of these small actively proliferating lesions in the apical coils and the vestibular system on the right is aided by a consideration of the general pathology of measles.

In their study of nasal smears during the coryza of measles Bryan and Bryan[16] found multinucleated cells similar to those described in tissue specimens from cases of measles.

Rake[17] described the lymphoid tissue in measles as becoming hyperplastic and containing multinucleated giant cells.

Koplik spots in the buccal mucosa consist of focal exudations of serum and endothelial cells which form vesicles followed by focal necrosis.

The skin rash starts around superficial vessels of the corium with exudation of serum, proliferation of endothelial cells, vesicle formation and desquamation. The central nervous system shows perivascular hemorrhages and lymphocytic infiltration followed by demyelinization. The foci which were still present in the ears in this case were similar to those found elsewhere in the body in measles except that there was more evidence of chronicity in some areas.

Clinical observations show that the measles virus causes deafness more often than damage to the vestibular apparatus. This is explained by the presence of the stria vascularis in the cochlea. This rich capillary bed is the most frequent site for the blood borne foci to appear. As a focus develops it tends to break through the surface layer of cells. Some loose cells are liberated in the endolymph. Some amorphous precipitate and an increased affinity for the stain also occur. The presence of these inflammatory or toxic alterations in the endolymph is apparently responsible for a degenerative change in the tectorial membrane and the hair cells. As the degeneration progresses the stria itself disappears as well as the supporting cells in Corti's organ. Hensen's cells are the last component of the organ to disappear. Coincident with the loss of supporting cells and pillars the nerve fibers become thinned out and the spiral ganglion cells reduced in number.

While this interpretation of the development of the degenerative process seems justified it does not explain the greater degree of degeneration in the basal coil as compared to the apex. There is no apparent reason for greater susceptibility of the stria in the basal coil to blood borne infecting agents.

One explanation for the degeneration of the sensory elements in the basal coil might be a greater concentration of toxic elements in that region. The absence of any collections of loose cells in the basal coil such as were present in the endolymph in the apex argues against any appreciable movement of endolymph in that direction.

The degenerative process in measles resembled that found in cases exposed to maternal rubella in that the stria appeared to be the primary site of the disease in the inner ear.

The ear appears to be susceptible to rubella only in the developing stage of the embryo particularly from about the sixth to the twelfth week. The resulting picture has been influenced by the stage in the development at which the disease occurred.

Th diagnosis of "acoustic neuritis" or "toxic neuritis" fails to indicate the nature of the process which has been described in this case since the inflammatory process involved the sensory apparatus primarily. The "neuritis" was secondary to degeneration of the end organ. The term "neurolabyrinthitis" is also open to objection since the neural degeneration was secondary and the labyrinthitis was limited to the endolymphatic system. The pathologic findings in this case might best be described as an "endolymphatic labyrinthitis" due to measles, with secondary degeneration of the peripheral cochlear neuron.

SUMMARY

1. Several surveys of deaf children have illustrated the frequency of deafness, impaired hearing and damaged vestibular function due to measles.

2. Only three descriptions of the inner ear in such cases have been found: one case with early complicating bacterial labyrinthitis, one case with healed labyrinthitis probably secondary to measles meningo-encephalitis, and a brief description of one case one year following an "acoustic neuritis" due to measles.

3. The pathologic changes in the ears are reported from a case of measles which illustrates the direct effect of the virus on the sensory structures.

4. Different stages in the degenerative process were illustrated. The lesions affected primarily the stria vascularis. Degeneration of the tectorial membrane and hair cells had occurred throughout. The supporting elements in Corti's organ had disappeared in the lower middle and basal coils accompanied by degeneration of the nerve fibers and ganglion cells as well as the disappearance of the stria vascularis.

5. In the vestibular labyrinth small proliferating granulomatous lesions were present in the wall of the utricle as well as in the macules of the utricle and saccule and in the cristas with secondary degeneration of the sensory cells.

6. The pathologic process caused by the measles virus in this case may be termed "endolymphatic labyrinthitis" with secondary nerve degeneration.

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LV

FURTHER STUDIES OF THRESHOLD SHIFTS AS MEASURED WITH THE BÉKÉSY-TYPE AUDIOMETER

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The Békésy-Type Automatic Recording Audiometer, with the addition of certain accessory equipment, is proving to be an exceedingly useful device for the measurement of changes in auditory sensitivity resulting from exposure of the ear to various types of sound stimulation. Use of the instrument facilitates measurement of the magnitude of the temporary threshold shift (TTS) within a few seconds after termination of a sound exposure and permits a continuous recording of the recovery of the sensitivity of the ear following the exposure. The degree of recruitment resulting from the exposure also is indicated by the number of threshold crossings per unit time, which are recorded on the audiogram.

The use and advantages of the Békésy audiometer for the measurement of the TTS resulting from sound stimulation was described by the authors in a recent paper on "Changes in Auditory Acuity Produced by Low and Medium Intensity Level Exposures."[6] The findings reported in that paper on normal ears may be summarized as follows: 1) 10 db sensation level (SL) pure tone exposures of 10 seconds' duration result in measurable threshold shifts; 2) slight recruitment is apparent at the post-exposure threshold level following the 10 db SL second pure tone exposures; 3) 20 db SL exposures of one minute's duration at 1000 cycles result in slightly greater shifts for the exposure frequency than do comparable 80 db SL exposures; 4) recovery is more rapid following the 80 db SL one minute exposures at 1000 cycles than the comparable 20 db exposures; and

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5) the magnitude of the TTS for the exposure frequently is not proportional to the intensity level of exposures of one minute's duration at 1000 cycles.

Figure 1 shows four measurements of typical threshold shifts obtained after 10 db SL ten second exposures at the indicated frequencies. The measurements are read from left to right. The intensity increases from top to bottom as on the conventional clinical audiogram. The horizontal lines represent intensity intervals in 10 db steps. A continuously variable intensity or "stepless" attenuator was used in making these and all other measurements illustrated in the present paper. All measurements were made with an attenuation rate of 2 db per second. The time scale along the x-axis represents a paper speed of 33 mm per minute in Figure 1. In all subsequent illustrations the paper speed is 8.3 mm per minute. The short straight horizontal line following and midway between the pre-exposure up and down excursions of the recording pen indicates the intensity level above which the exposure was presented and also the duration of the exposure. The difference between the intensities of the mid points of the pre- and post-exposure threshold values indicates the magnitude of the temporary threshold shift resulting from the exposure. The measurements in Figure 1 show shifts of 3.5 to 5 db in magnitude. Also slight recruitment at the post-exposure threshold intensity level as indicated by the shorter up and down excursions of the recording pen immediately following the exposure. Note how the amplitude of the swing of the pen increases as the sensitivity recovers to the pre-exposure level.

Figure 2 shows three typical sets of paired 20 db (A) and 80 db (B) SL measurements from three experienced subjects. The exposure and recovery were at 1000 cycles and the duration of the exposures one minute. Note that the shifts are greater following the 20 db SL exposures and that the threshold sensitivity does not return to quite the pre-exposure value even after several minutes of recovery following the 20 db exposures. The recovery curves following the 80 db exposures are steeper than those following the comparable 20 db exposures, indicating more rapid recovery following the 80 db SL exposures. Also note that the recovery curves following the 80 db exposures shows the post-exposure sensitivity, about two minutes after termination of the exposure, to be greater than the pre-exposure sensitivity. This aspect of the recovery will be discussed later.

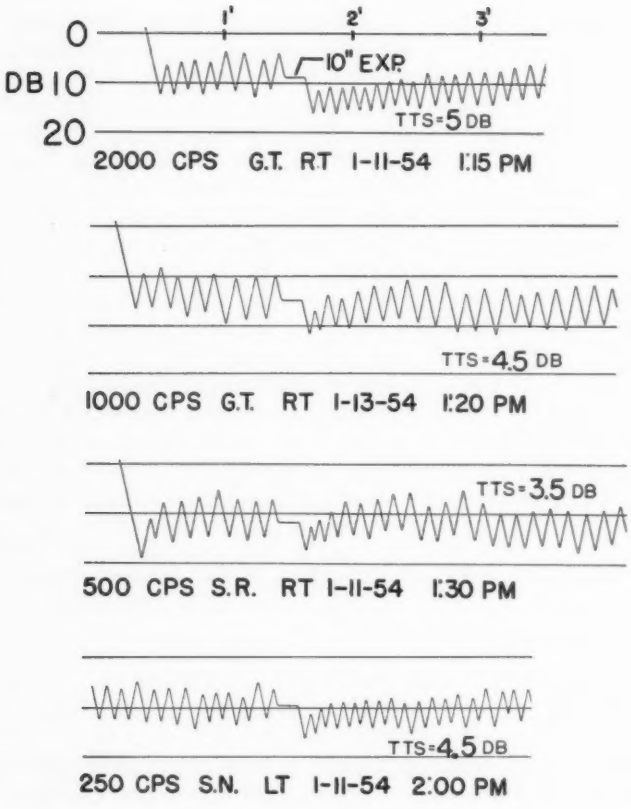

Fig. 1.—Temporary threshold shifts resulting from 10 second 10 db SL exposures.

The present paper presents three additional experiments, the results of which provide further data on the nature of the TTS resulting from low and medium intensity level exposures. Most of the measurements were made on four highly trained subjects, each of whom had normal hearing. However, data were obtained on several visitors to the laboratory in each of the experiments with no contradictory results. Trained subjects, who are able to appear at appropriately scheduled times, are preferred for measurment purposes. Such individuals usually are able to disregard the tinnitus which may result from relatively high intensity level exposures. And until a subject has sufficient listening experience to become conditioned to the experimental procedure and form a stable perceptual criterion of just when he does and does not hear a sound which is gradually increasing or decreasing in loudness, his responses may show considerable variability from measurement to measurement for reasons other than variation in sensitivity of the end organ itself.

EXPERIMENT I

The effect of bilateral simultaneous but unequal SL exposures on the ear exposed to the lower SL was determined. The pre-exposure thresholds were obtained first in one ear and then the other by means of two separate Békésy-Type audiometers. The same frequency from a single oscillator was fed to the input of each audiometer by means of a hybrid coil, a special type of transformer having three separate windings, each with the same turns ratio. The output from each audiometer terminated in a moving coil or dynamic receiver. The accessory timer, relays and external exposure attenuators were adjusted so that both ears were exposed simultaneously to a 1000 cycle tone for one minute, the right ear at a 20 db SL, the left at a 40 db SL. During the exposure the sound was perceived only in the left ear—the ear exposed to the higher SL tone. (Lateralization resulting from simultaneous but unequal bilateral loudness level exposures with the same frequency constitutes the basis of the well-known Stenger test for the detection of unilateral auditory malingering.) At the termination of the exposure, the threshold sensitivity of the right ear—the ear in which no sound was heard during the exposure—was measured. Five measurements were obtained on each of the four trained subjects, which were compared with the same number of comparable measurements following unilateral one minute 20 db exposures at 1000 cycles on the right ears as a control. The unilateral control shifts had a mean value of 8.4 db with a standard

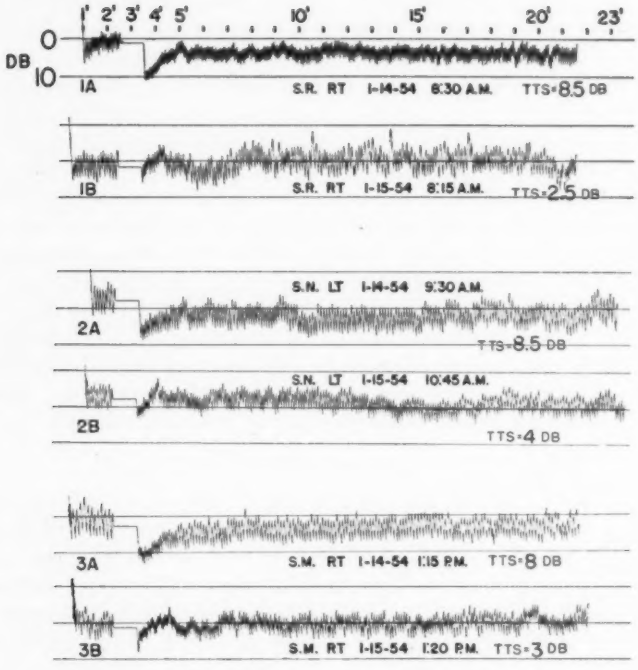

Fig. 2.—Paired shifts resulting from one minute 20 db (A) and 80 db (B) SL exposures at 1000 cps.

deviation of 1.78. The comparable shifts for the right ears of the same subjects following the Stenger exposures had a mean value of 8.1 db with a standard deviation of 1.85. This result indicates that a sound need not be perceived to produce a decrease in auditory sensitivity. It also indicates that the anatomical locus of the structures involved in the shift resulting from low SL stimulation is below the neurological level at which bilateral stimuli combine in consciousness in the auditory system.

This experiment agrees in principle with a study reported by Pattie,[4] who exposed both ears simultaneously " . . . for one minute with a loud tone of 512 cycles . . . conducted from a telephone receiver in a sound-proof box through a Y-tube, the branches of which

were connected to rubber tubes leading to the subject's ears. The loudness of the tone at the receiver was 130 'sensation units.' The length of tubing from the source to the ear was about 6.3 m. The diameter of the tubing was 1.5 cm. The tube leading to one ear was lengthened so as to throw the tone in that ear approximately half a wave-length behind the other tone. Localization of the binaural tone was entirely on the side of the leading phase. This change in phase did not cause any appreciable differences in the intensities of th two tones." After the bilateral exposures described above by Pattie, "Two tones, very near subjective equality when the ears are normal, were successively presented, one in each ear, for comparison after the minute-long stimulation." He found that "both ears are equally fatigued by such stimulation." Pattie concluded that auditory "fatigue" is a peripheral rather than a central phenomenon.

EXPERIMENT II

The threshold shift for a pure tone which was masked with white noise during the exposure was investigated. The equipment was modified to enable simultaneous presentation of the pure tone and the white noise during the exposure and to attenuate automatically the white noise below audibility while obtaining the pure tone pre- and post-exposure thresholds. The one minute exposure consisted of a simultaneous presentation of a 1000 cycle tone at a 20 db SL plus white noise at a sufficiently high intensity level to just mask the pure tone. Consequently, during the exposure only the white noise was perceived. (An approximate 40 db SL white noise is required to mask a 20 db SL 1000 cycle tone in the normal ear.) At the termination of the exposure the white noise was attenuated below audibility and the post-exposure threshold sensitivity for the 1000 cycle tone determined. It was found that no difference existed between the pre- and post-exposure thresholds for the pure tone. Apparently a one minute 20 db SL pure tone exposure which is just masked with white noise does not produce a threshold shift for the pure tone. As indicated in Experiment I, a one minute 20 db SL exposure at 1000 cycles produced a mean shift of 8.4 db for itself on four trained subjects, five measurements being obtained on each.

Recent data from an unpublished study by Reger and Nakamura[7] on "The Effect of Low and Medium Intensity Level White Noise Exposures on Threshold Sensitivity for White Noise and Pure Tones" shows that a one minute 40 db SL white noise exposure pro-

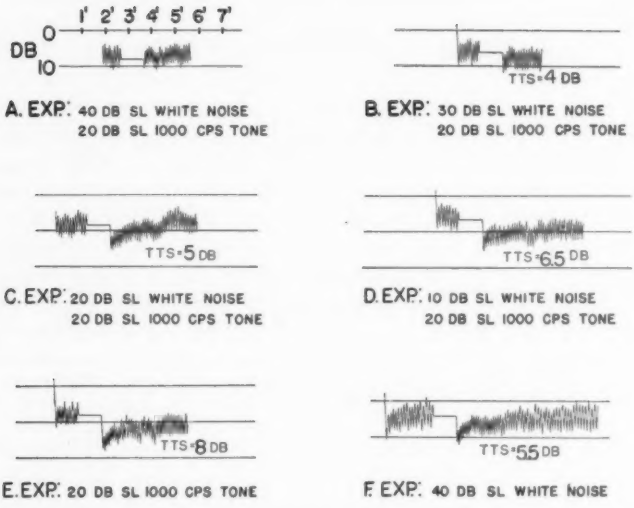
1' 2' 3' 4' 5' 6' 7'
DB
0
10
A. EXP.: 40 DB SL WHITE NOISE
20 DB SL 1000 CPS TONE
TTS=4 DB
B. EXP.: 30 DB SL WHITE NOISE
20 DB SL 1000 CPS TONE
TTS=5 DB
C. EXP.: 20 DB SL WHITE NOISE
20 DB SL 1000 CPS TONE
TTS=6.5 DB
D. EXP.: 10 DB SL WHITE NOISE
20 DB SL 1000 CPS TONE
TTS=8 DB
E. EXP.: 20 DB SL 1000 CPS TONE
TTS=5.5 DB
F. EXP.: 40 DB SL WHITE NOISE

Fig. 3.—In A, B, C, D and E the pre- and post-exposure threshold measurements are at 1000 cps: in F the pre- and post-exposure threshold measurements are for white noise. All exposures had a duration of one minute.

duces less than one db shift at 1000 cycles on trained subjects. However, they found that white noise exposures have an appreciable effect on the post-exposure sensitivity to white noise itself. Five measurements were obtained on each of the four trained observers in the following manner: 1) by means of a Békésy-Type audiometer the threshold sensitivity for the white noise was ascertained; 2) the ear was exposed to the white noise for one minute at the 40 db sensation level; and 3) at the termination of the exposure the threshold shift for the white noise was determined. It was found that the one minute 40 db exposures produced a mean shift of 6.1 db, with a standard deviation of 1.9 db.

The fact that a one minute exposure consisting of a 20 db SL pure tone which is just masked with a 40 db SL white noise does not result in an appreciable shift for the pure tone presents an interesting observation. The phenomenon appears paradoxical since: 1) Experiment I presents evidence which shows that a sound need not be

perceived to produce a shift; 2) a one minute 20 db SL 1000 cycle exposure produces a shift of 8.4 db for itself; and 3) a one minute 40 db SL white noise exposure produces a shift of 6.1 db for itself.

Figure 3 shows a set of typical measurements made on an experienced subject with normal hearing. Measurement A shows the absence of any appreciable shift following a one minute masked exposure consisting of a 20 db SL 1000 cycle pure tone and a 40 db SL wide band white noise. Measurements B, C and D each contained the 1000 cycle tone at the 20 db SL, with the white noise presented at a 30 db SL in B, at a 20 db SL in C and at a 10 db SL in D. The 1000 cycle tone was perceived at progressively higher loudness levels in B, C and D, resulting in progressively greater shifts for the pure tone. Measurement D shows a typical threshold, shift and recovery for a 1000 cycle pure tone following a one minute 20 db SL exposure at 1000 cycles. Measurement F shows a typical pre-exposure threshold, shift and recovery for white noise following a one minute 40 db SL white noise exposure. A satisfactory explanation of this phenomenon awaits further study.

EXPERIMENT III

This experiment is designed to measure the effect of a series of briefly interrupted cumulative intensity level exposures on the sensitivity of the ear. The interval between each exposure is the shortest duration which permits a measurement of the shift before presentation of the next exposure. Two or three threshold crossings, requiring approximately 12 seconds, usually are sufficient to indicate the extent of the shift after each exposure.

Figure 4 presents typical paired 20 db (A) and 80 db (B) SL measurements on three trained subjects with normal hearing, showing the shifts at 1000 cycles resulting from 30 briefly interrupted successive one minute 1000 cycle exposures. The first five, plus the 10th, 15th, 20th, 25th and 30th exposure levels and shifts are shown. In these measurements each exposure except the first was presented at a 20 db SL in *A* and an 80 db SL in *B* above the shifted threshold value resulting from the previous exposure. For example, the top series of measurements, 1A, show a shift of 9 db after the first 20 db SL measurement. The second exposure was presented 20 db above this shifted value, or 29 above the original pre-exposure level, and so on throughout the series of 30 exposures. Analysis of the paired series of measurements shows that after a few exposures little or no

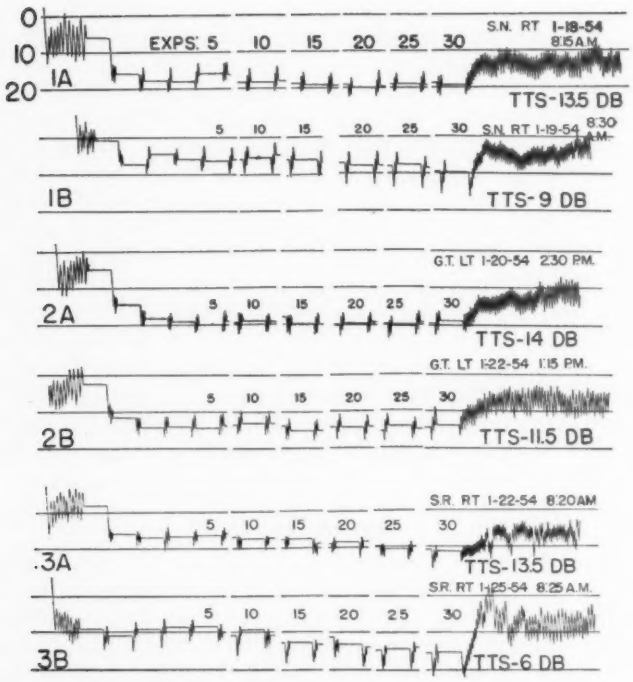

Fig. 4.—Paired shifts resulting from cumulative intensity one minute 20 db (A) and 80 db (B) SL exposures at 1000 cps.

additional shift occurs. Under the given set of exposure parameters illustrated in Figure 4 it is apparent that the sensitivity of the ear decreases rather rapidly to a certain equilibrium or saturation level, after which resistance to the effect of additional exposures is greatly increased. Comparisons between the 20 db and 80 db SL exposures also show that even after 30 consecutive one minute exposures at 1000 cycles, separated by relatively brief rest or recovery periods, a greater shift results from the 20 db than from the 80 db SL exposures in trained normal ears at 1000 cycles.

Figure 5 shows a series of five one minute, cumulative intensity, 20 db SL exposures at 4000 cycles on a pathologic ear. This subject

had normal threshold sensitivity up to and including 2000 cycles with an 80 db bilateral loss at 4000 cycles. The etiology is uncertain. However, the pre-exposure threshold sensitivity measurement at 4000 cycles shows the presence of recruitment, which is indicative of cochlear pathology at this frequency level. The irregular response at T, immediately following the last exposure—the fifth—indicates the presence of tinnitus which interfered with the subjects' perception of the 4000 cycle tone, after which no additional exposures were given. *R* indicates a rest interval, during which the tone was attenuated below audibility for approximately two minutes. It is interesting to note that the "rest" accelerated the recovery but that the threshold sensitivity decreased approximately 7 db rather rapidly after the "rest, showing a "'tenderizing" effect of the previous exposures. The last measurable shift of Figure 5 shows a final shift of 28 db. Consequently, the last exposure was 48 db above the subjects' pre-exposure threshold value. Since he had a hearing loss of 80 db for the exposure tone, this last exposure was 128 db above the threshold value of the normal ear at 4000 cycles. Comparable measurements at 4000 cycles of normal ears await future investigation.

A modification of procedure in which the recurrent exposure tone is always presented at the same intensity level above the initial pre-exposure threshold value may be desirable for certain purposes. Since high intensity level pure tone exposures produce a greater shift for frequencies one-half octave to an octave higher than the exposure frequency, in order to produce the maximum shift, the ear should be exposed to a given frequency and the shift measured at a higher frequency level. Since the ear is particularly susceptible to trauma near 4000 cycles a logical choice of parameters includes an exposure frequency of 3000 cycles and a shift frequency of 4000 cycles.

It is believed that the effect of high intensity level exposures can be investigated with complete safety to the subject by means of this type of "periodic shift sampling" exposure technique. If, as a result of this procedure the post-exposure thresholds do not show a logarithmic or exponential decrease in the magnitude of successive shifts and do not reach an equilibrium level before a given predetermined "danger level" shift results, the exposures can be discontinued before trauma occurs. Temporary threshold shifts on normal ears as great as 50 db, requiring several hours for recovery, are under investigation at the present time.

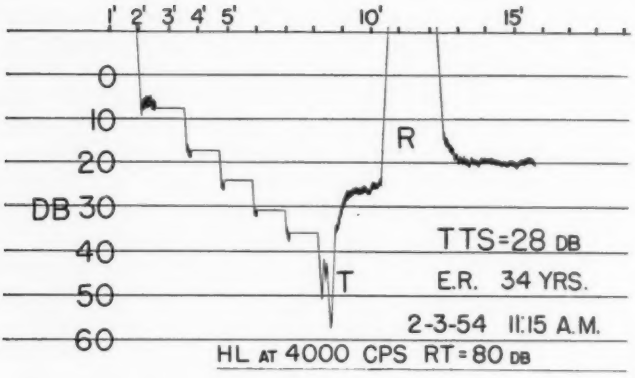

Fig. 5.—TTS resulting from cumulative intensity one minute 20 db SL exposures at 4000 cps.

DISCUSSION

The experiments and measurements described suggest several implications of more than casual interest. It appears that the thresholds sensitivity of the ear is more susceptible to fluctuation from low intensity level sound exposures than formerly realized. This probability has a direct bearing on the testing technique employed in clinical pure tone audiometry. The initial presentation of the pure tone should not have a duration of more than two or three seconds and should be at a low intensity level. The threshold should be approached only from inaudibility to audibility. The fact that such relatively low intensity level, short duration exposures produce measureable threshold shifts suggests that some part of the auditory mechanism is susceptible to frequent and relatively rapid decreases in sensitivity resulting from the ambient noise levels which are unavoidable in every day life. Recovery from such shifts is correspondingly rapid with little or no after effects. The results of the 30 successive cumulative intensity level exposures at the 20 db and 80 db SL suggest that the shift resulting from low intensity level exposures is highly resistant to increase until relatively great intensity noise levels are encountered. It seems reasonable to assume that the mechanism responsible for the shift resulting from ordinary noise levels protects

the ear from the cumulative effects of every day ambient noise. However, when sound pressures exceed certain critical intensities and durations this mechanism of the ear is inadequate to protect against acoustic insult, and trauma results.

The finding that usually there is less shift and more rapid recovery at 1000 cycles following a one minute 80 db SL exposure at 1000 cycles than for the comparable 20 db exposure, indicates that the magnitude of the TTS is not always proportional to the intensity level of the exposure. As a matter of fact, recovery curves following the 80 db exposures (Fig. 2) show that the sensitivity about two minutes after termination of the exposure is greater than that of the pre-exposure sensitivity. As early as 1936 Bronstein[1] reported that: "Sounds can . . . not only cause a decrease, but also an increase of sensitivity of the auditory organ . . . It is highly probable that the sensibilisation is due to processes taking place in the receptive nervous apparatus . . . "

A somewhat different picture results when the shifts for frequencies other than the stimulating tone are measured. Causse and Chavasse[2] found the maximum shift to be for the stimulating frequency itself after 40 db sensation level exposures. On the other hand Rawdon-Smith[5] found that high intensity level exposures result in the maximum shift for frequencies higher than the exposure tone. Milstein,[3] investigating the frequency specificity of the shift following one minute, 1000 cycle, 10 to 100 db sensation level exposures on trained normal ears, found the maximum shift to be slightly greater for frequencies higher than the stimulating tone following the 80 db exposures. However, the shift for 1000 cycles following the 20 db SL 1000 cycle exposure was greater than the shift for any frequency following the 1000 cycle 80 db exposures.

Bronstein[1] dismissed the action of the middle ear muscles as a factor in the sensitization of the ear following his exposures. However, the writers feel that the possibility that the intra-tympanic muscles may modify the magnitude of the shift and the characteristics of the recovery curve has not been eliminated.

SUMMARY

1. The threshold sensitivity of the ear is susceptible to frequent and relatively rapid fluctuations resulting from the ordinary every day noise environment. Recovery of the sensitivity following

such exposures is correspondingly rapid, with little or no after-effect. However, the shift resulting from low intensity level exposure is exceedingly resistant to increase in magnitude until relatively high intensity level exposures are encountered.

2. Determination of the pure tone threshold sensitivity should be performed by approaching the threshold from inaudibility to audibility.

3. Shifts may be produced by sounds which are not heard.

4. Low intensity level pure tone masked exposures do not result in shifts for the pure tone.

5. The magnitudes of temporary threshold shifts are not always proportional to the intensity levels of the exposures.

6. The action of the intra-tympanic muscles may modify the extent of the shift and the characteristics of the recovery curve following relatively high intensity level exposures.

7. A cumulative intensity or constant intensity series of interrupted exposures permits observation of the slope and extent of the shifts as they develop during the exposure series. This technique permits termination of the exposures when a given pre-determined magnitude of shift has been produced.

University Hospital.

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LVI

CLINICAL STUDY OF BONE CONDUCTION AUDIOMETRY

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AND

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The accurate measurement of severe unilateral hearing loss presents a rather complex process and continues to challenge the otologist and audiologist. Such measurements involve masking phenomena, noise audiometry and bone conduction appraisal. Hawkins and Stevens[5] corroborated previous investigations on masking measurements by thermal noise and extended their study to include other variables as well. Fletcher[4] calculated the critical band widths and also indicated that the critical band widths are not constant for all tones. In his elaborate treatment he reveals the intimate relationships between masking and loudness phenomena. Stevens and Davis[9] made certain suggestions concerning the relationship between the masked and the masking stimuli.

This research suggests that a low tone is usually effective in masking a high tone but also that the more effective masking stimuli lie close to the masked variable. Licklider[7] considers the critical band width concept and indicates relationships that would provide explanatory principles. Yet it is common clinical observation that the masking tone in the commercial audiometers does not effectively mask the higher frequencies when testing for severe unilateral loss.

Hirsh[6] indicates that the maximum masking spectra in the usual commercial audiometer would probably not successfully mask contralateral ears with losses greater than sixty decibels. Even so, it is possible to occupy the good ear so that some satisfactory measure-

Fig. 1.—Equipment utilized in the water-douching experiment.

ment of the contralateral poorer ear may be obtained by air conduction. The question is complicated when bone conduction measurements are desired.

The fundamental contributions by Bárány,[1] Békésy,[2] and Rosenblith,[3] suggest reasons for the present difficulty in securing reliable bone conduction measurements. Inertia bone conduction does not disappear even for the high frequencies and in the middle frequency and high frequency tones bone inertia and compression bone conduction appear to be present. Furthermore, inertia bone conduction appears to test both ears. Wever and Lawrence[11] reveal that this knotty problem of bone conduction measurement is not a novel phenomena but has a rather long history. They specifically

Fig. 2.—Equipment and subject in position in the water-douching experiment.

consider the relative motion in bone conduction measurements and also speculate concerning possible secondary pathways.

Hirsh[6] gives a good deal of consideration to bone conduction and suggests that even at this date bone conduction measurement is still in a transition stage. He points out that one of the reasons for the difficulty of the problem is that the input is not precisely measured and furthermore, that the acoustic impedance of the skull varies at different points. Palva, Goodman, and Hirsh,[8] chart out a historical review of noise audiometry and speculate that masked thresholds are not useful indicators for differential diagnosis since critical band concept makes such an hypothesis untenable. Weille and Gargano[10] reiterate the hypothesis concerning the presence of multivariables in testing bone conduction and also point out the variability among commercial audiometers. They also suggest that speech audiometry

helps to corroborate bone conduction measurement but foresee possibilities for overmasking.

Since the usual procedures utilizing air-borne acoustic stimuli for masking purposes provide so many opportunities for error for accurate bone conduction measurement, it was speculated that perhaps some other masking means might prove fruitful and desirable, consequently the present study is an exploratory one, designed to measure the effects of water douche masking on air and bone conducted sounds. The results would then be compared with the more conventional masking techniques employing white and saw-tooth noises. Furthermore, the study was designed to determine the effect of water douche masking on the threshold sensitivity on the unmasked ear.

The instrumentation employed in all of the measurements concerned with douching included a 2½ gallon bottle with a bottom spout. The spout was connected by 32 inches of 3/16 inch I.D. rubber tubing to a glass "Y" connection, which was in turn fastened by two 18 inch pieces of rubber tubing to two cannulae, each with ⅛ inch lumina. The bottle was placed at a height of 59 inches above the floor, so that with sitting subjects, the spout was at a distance of approximately 11 to 12 inches above the ear. Figure 1 shows this equipment. Figure 2 presents it in operation. Before the tests were begun, the bottle was filled to its capacity with water at 98 degrees F. and was not allowed to empty itself to a level less than one-fourth its capacity before replenishing. Early in the use of this technique, several variables of importance were discovered. To be successful with water-douche masking, the ear canal must be sealed, that is, at all times the canal must be full of water. This requires the use of a cannula with a relatively large bore and a careful application of the cannula to the entrance of the meatus so that the stream is directed in the axis of the canal and not against one of its walls. This is easy to accomplish in a large canal but difficult in a small or sharply angulated one. The noise created by the water may be one factor responsible for the masking produced by this method. If the stream is directed against the drum the noise will be louder than if it impinges on the canal wall. The pressure of the water is another variable which must be kept in mind during the placement of the cannula into the meatus. It is our opinion that an otolaryngologist should adjust the cannula to the ear. During our sequence of tests, two people were usually required, a physician to manipulate the

douching apparatus, another person to secure the audiometric thresholds. When simultaneous bilateral douching was performed, another doctor was needed to direct the second cannula.

Sound field measurements, as well as water-douch thresholds, were obtained in a sound-treated room, using hearing aid evaluation equipment which, as a large system, is capable of delivering electrically flat signals of 50-15000 cps at an intensity of 110 db at a distance of four feet from the speaker. The equipment, including the tone oscillator and a 50 watt amplifier, was in an adjoining room; the 15 inch Altec speaker, mounted in a bass reflex cabinet, was in the isolated sound field. Audiometric measurements were obtained with standard pure-tone audiometers with hearing aid type bone conduction receivers.

A group of twenty university students, having hearing losses no greater than 10 db at any one frequency and evidencing no history of aural pathology, was selected as the sample. After an examination of the ears to eliminate any who might have exhibited pathology, particularly perforated membrana tympani, the following tests were made:

1) Judgment of equal loudness between the noise created by douching and a comparable noise in the contralateral ear; 2) sound field thresholds obtained during simultaneous bilateral douching; 3) bone conduction thresholds, each ear, obtained during simultaneous bilateral douching; 4) sound field thresholds, each ear, obtained while douching the contralateral ear; 5) bone conduction thresholds, each ear, obtained while douching the contralateral ear; 6) bone conduction thresholds, each ear, obtained while douching the ipsolateral ear.

The study was later extended to include 21 individuals with unilateral hearing losses. Each of these subjects, except one who had suffered a vascular accident, had previously been subjected to a labyrinthotomy with destruction of the labyrinth (the Day operation). In each of these individuals, as well as could be determined, the hearing in the operated ear had been completely destroyed. The authors are grateful to Dr. Kenneth Day of the University of Pittsburgh and to Dr. Theo Walsh of Washington University, who were kind enough to conduct a portion of the tests on subjects furnished by them so that this total number might be available for study. This group of individuals was chosen so that it would be reasonably certain that only one ear at a time was being tested while obtaining

comparison of the masking effects of white and saw-tooth noise, and of the water douche for air and bone conducted sound. Although the attempt was made to select only those individuals who showed no appreciable hearing loss in the better ear, many of the sample displayed impairment of varying degree in that ear. Since it is easier to mask out a response when a hearing loss is present, not all of the measurements obtained were used in the final analysis. If a loss greater than 20 db existed for any frequency, either by air or bone conduction, that measurement was excluded from the data in the following tables.

Although data obtained with the two types of noise masking for all three of the examiners are included in the results, only those water-douche measurements performed by the examiners are included. This results in a reduced total N for these individuals participating in the water douche tests.

The measurements employed with these individuals with unilateral hearing losses include: 1) audiometric pure-tone thresholds for the poorer ear obtained with contralateral masking using 80 db sawtooth noise, 80 db white noise, and the water douche; 2) bone conduction thresholds for the poorer ear, obtained with contralateral masking using 80 db sawtooth noise, 80 db white noise, and the water douche.

The 80 db intensity level for the saw-tooth and white noises were chosen because recent literature has advanced the notion of the desirability of this level and because 80 db is the approximate maximum intensity level of the masking circuits provided on most commercial audiometers.

Normal-hearing Subjects. The first test utilized with the group of individuals with normal hearing was designed to measure, as closely as possible, the sensation level of the water stream in the external meatus. A binaural equal-loudness judgment was required from each individual. He was asked to indicate when a 128 cps tone in one ear was considered by him to be of equal loudness to the sound of the flowing water in the contralateral ear. This particular reference frequency was chosen after the examiners had listened to the tone in their own ears and had agreed that the fundamental frequency components of the perceived sound were probably to be found in the lower frequencies. It will be observed from Table 1 that the

TABLE 1.—LOUDNESS OF WATER DOUCHE AS MEASURED BY BINAURAL COMPARISON WITH CONTRALATERAL 128 cps PURE TONE FOR TWENTY NORMAL-HEARING INDIVIDUALS.

	DOUCHE RIGHT EAR TONE LEFT EAR	DOUCHE LEFT EAR TONE RIGHT EAR
Mean db	41.9	42.0
Standard deviation	11.1	11.8

loudness level of the noise introduced by water douching is relatively low when one remembers the noise level utilized in conventional masking techniques.

So that an estimate could be made of the masking effect of water douching for air-conducted sound, both ears of each subject were douched at the same time while pure-tone thresholds were measured in the sound field (Test II). Note that these thresholds shown in Table 2, are considerably higher than might be expected if the masking effect of the water were dependent only on the inherent noise of the water stream. The difference between median and mean scores, particularly at 500 cps, is probably due to the 110 db upper limit of the acoustic system employed; in many cases, no response whatsoever could be elicited even at this maximum intensity. These figures also suggest that water-douche masking has a greater effect on the two lower frequencies than on the two higher ones. If, after eliminating the scores of the individual on which only three frequencies were measured, the remaining scores are arranged so that two distributions result, one containing 38 scores at 500 and 1000 cps, the other containing an equal number of scores representing 2000 and 4000 cps, the means for these two distributions are 93.2 and 83.7 respectively with the higher mean representing greater masking effect for the lower frequencies. The technique for comparing differences between means of correlated data may then be employed. The resulting t of 4.26 is significant at the .01 level of confidence so that there appears to be an approximate 10 db greater masking effect of the water douche for lower frequency sounds of 500 and 1000 cps as compared to the higher frequencies of 2000 and

TABLE 2.—MEANS, MEDIANS AND STANDARD DEVIATIONS OF SOUND FIELD PURE TONE THRESHOLDS OBTAINED DURING BILATERAL DOUCHE FOR NORMAL HEARING INDIVIDUALS.

	MEAN DB	MEDIAN DB	STANDARD DEVIATION	NUMBER OF CASES
500 cps	92.0	98.0	15.2	19
1000 cps	93.0	95.0	14.9	20
2000 cps	80.9	84.0	15.7	20
4000 cps	83.3	85.0	14.6	20

4000 cps. It may be speculated that this difference in masking efficiency might be accounted for by the low frequency components of the water stream as it is directed on the tympanum. This, of course, would result in an increased masking effect for those frequencies close to the masking sound.

In Test III, a similar attempt was made to measure the effectiveness of water-douche masking for bone conduction. Each ear was tested separately for bone conduction thresholds while both ears were simultaneously douched. These thresholds (Table 3) suggest that this technique has a marked effect in reducing the sensitivity of the ear to bone-conducted sound. The authors are at a loss to explain the discrepancy between the means obtained for the right and left ears at 4000 cps except by chance variation. There is no evidence of a constant error which might have acted to raise or lower one of these means. In view of evidence to be presented later in the paper, it may be reasonable to suspect that the mean for the left bar (40.5) is the more valid one, although this cannot be strongly supported because of the few measurements available at this frequency from the unilaterally deafened individuals. It is also difficult to account for any large threshold shift induced by water douching. Although the mass of water in the meatus might be operative in the masking of air conduction, it is not likely to affect bone conduction transmission. Similarly, 40 to 45 db changes in bone conduction thresh-

TABLE 3.—MEANS AND STANDARD DEVIATIONS OF BONE CONDUCTION THRESHOLDS OBTAINED DURING SIMULTANEOUS BILATERAL DOUCHE FOR TWENTY NORMAL-HEARING INDIVIDUALS.

	BONE CONDUCTION RIGHT EAR WITH SIMULTANEOUS BILATERAL DOUCHE		BONE CONDUCTION LEFT EAR WITH SIMULTANEOUS BILATERAL DOUCHE	
	MEAN DB	STANDARD DEVIATION	MEAN DB	STANDARD DEVIATION
500 cps	43.8	8.4	47.6	4.2
1000 cps	47.2	9.0	48.9	8.9
2000 cps	42.2	12.1	45.0	11.7
4000 cps	32.7	10.8	40.5	12.6

olds cannot logically result from a 40 db sensation level of noise caused by the running water. It would appear that factors, other than noise and mass, are, in all likelihood responsible for the greater part of the threshold change.

Much attention has been given to the problem of the intensity of the masking noise when conventional techniques are employed and the dangers of overmasking. The purpose of Tests IV and V was to estimate the effect of douching on the air and bone conduction thresholds of the contralateral ear. One might expect that, because of the relatively low noise level of water douching, opposite ear sensitivity would change but slightly. The data shown in Tables 4 and 5 seem to lend support to this notion; most of the obtained thresholds fall below 5 db.

Table 6 refers to the thresholds obtained by bone conduction when the ipsolateral ear is douched (Test VI). It would seem not unreasonable, in view of the findings of Test III, to assume that douching the ipsolateral ear should result in elevated thresholds for that ear because of the proximity of the douche to the cochlea nearest the bone conduction receiver, but since approximately 40 db of mask-

TABLE 4.—MEANS AND STANDARD DEVIATIONS OF SOUND FIELD PURE TONE THRESHOLDS OBTAINED WHILE DOUCHING THE CONTRALATERAL EAR FOR NORMAL HEARING INDIVIDUALS.

	DOUCHE RIGHT EAR, TEST LEFT EAR— AIR CONDUCTION, SOUND FIELD			DOUCHE LEFT EAR, TEST RIGHT EAR— AIR CONDUCTION, SOUND FIELD		
	MEAN DB	STANDARD DEVIATIONS	NUMBER OF CASES	MEAN DB	STANDARD DEVIATIONS	NUMBER OF CASES
500 cps	4.2	4.0	20	4.2	4.1	19
1000 cps	4.6	4.0	19	6.0	3.3	19
2000 cps	1.4	1.8	19	2.0	3.7	19
4000 cps	3.4	3.0	18	4.3	5.9	19

ing results under these conditions, it might be inferred that the thresholds obtained in Test VI where the douched ear is tested are shadow representations of the unmasked, untested ear. In fact, one subject about midway in the group of twenty volunteered the information that he heard the tone in the unmasked untested ear. Subsequently, each subject was asked in which ear he heard the tone and a majority of them referred the tone to the ear opposite the bone conduction receiver.

Unilaterally-deafened Subjects. Comparing the efficacy of water-douche masking with masking methods untilizing white and saw-tooth noises, using individuals with no known hearing in the poorer ear seemed desirable as an extension of the present study. As mentioned earlier, Drs. Day and Walsh furnished much of the data related to noise masking, the authors added to this and included douching as a further measure.

In Table 7, audiometric air conduction thresholds for the poorer ear, obtained with contralateral masking of the three types, are shown together with the number of cases on which each one is based. It will be noted that the number of individuals in the group tested with the water douche is comparatively small. In spite of this, little difference appears between the three methods. The ten-

TABLE 5.—MEANS AND STANDARD DEVIATIONS OF BONE CONDUCTION THRESHOLDS OBTAINED WHILE DOUCHING THE CONTRALATERAL EAR FOR NINETEEN NORMAL-HEARING INDIVIDUALS.

	DOUCHE RIGHT EAR, TEST LEFT EAR— BONE CONDUCTION		DOUCHE LEFT EAR, TEST RIGHT EAR— BONE CONDUCTION	
	MEAN DB	STANDARD DEVIATION	MEAN DB	STANDARD DEVIATION
500 cps	3.4	7.2	2.9	6.9
1000 cps	4.6	9.2	4.8	5.4
2000 cps	5.2	8.3	3.9	8.6
4000 cps	5.4	2.0	4.6	8.6

dency for water douching to produce somewhat less masking for the two higher frequencies, as observed with the normal group, is perhaps obscured by the fact that, although measurements for better ear thresholds were eliminated from the table at frequencies where greater than a 20 db loss was found, a large number of cases exhibited losses of from 10 to 20 db at 2000 and 4000 cps. If this is taken into consideration, the impression is that these test results are not unlike those obtained during simultaneous douching with the normal hearing group.

In the case of bone conduction (Table 8), there appears to be little difference between the three methods of masking save at 500 cps. At this frequency, masking by white noise is apparently less effective than the other two methods. This is, perhaps, the expected result when the composition of white noise is taken into consideration.

Prior to testing the hearing of the subjects by bone conduction under the above conditions, a study of the difference in bone conduction readings of the unoperated and operated ears was made with no attempt to mask either ear. The results are shown in Figure 3, indicating that the difference between the ears is in the order of 10 db with a tendency for higher frequency sounds to display a larger

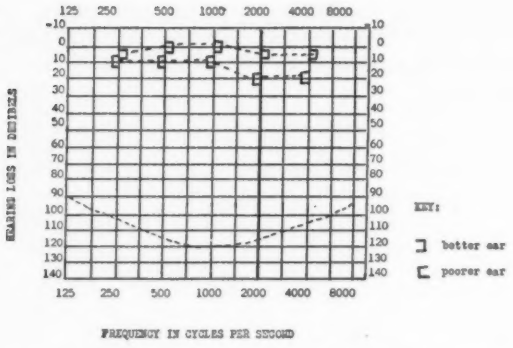
125 250 500 1000 2000 4000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
HEARING LOSS IN DECIBELS
KEY:
better ear
poorer ear
FREQUENCY IN CYCLES PER SECOND

Fig. 3.—Audiogram showing mean unmasked bone conduction responses for the better and poorer ears of individuals with unilateral hearing losses.

difference between better and poorer ears. This is, it seems, consistent with the findings of Weille and Gargano,[10] who indicate a greater "drop through the skull" for high frequencies than for low frequency sounds. The depression of the unmasked measurements for the poorer ear are, in all probability, related to the differences in the effectiveness of water douching as recorded in Table 8 for the unilaterally-deafened individuals and those represented in Table 3 for those subjects with no pathology of the hearing mechanism.

Tests were performed by each of the three examiners to obtain air and bone conduction readings for the better ear with the three methods of masking successively applied to the poorer ear. No tables of these tests will be presented since the variation in results between examiners precludes the possibility of meaningfully evaluating the data. An examination of the data, however, leads the authors to feel that there is less likelihood of overmasking with the water-douche method than with high intensity saw-tooth or white noise, particularly at the higher frequencies.

Since the above measurements had been made on normal-hearing and unilaterally-deafened persons, water-douching has been employed as a supplementary examination procedure for a group of six subjects with unilateral deafness due to disease. Due to the in-

TABLE 6.—MEANS AND STANDARD DEVIATIONS OF BONE CONDUCTION THRESHOLDS OBTAINED WHILE DOUCHING THE IPSOLATERAL EAR FOR TWENTY NORMAL-HEARING INDIVIDUALS.

	DOUCHE RIGHT EAR, TEST RIGHT EAR— BONE CONDUCTION		DOUCHE LEFT EAR, TEST LEFT EAR— BONE CONDUCTION	
	MEAN DB	STANDARD DEVIATION	MEAN DB	STANDARD DEVIATION
500 cps	11.7	7.7	13.3	7.4
1000 cps	11.6	5.4	13.6	4.5
2000 cps	11.4	5.9	12.8	8.4
4000 cps	14.0	8.1	16.2	8.6

herent difficulties in masking, it was impossible to be sure that there was total hearing loss in these patients. The results obtained, however, were consistent with the clinical impressions of the nature and magnitude of the loss. The masking effect was comparable to that obtained in the normal and operated subjects.

It is not possible for us to enumerate the elements in water-douching responsible for the masking effect. We can only mention some of the possibilities which seem to be related to the obtained results. In the first place, we feel that the noise produced by the stream entering the ear is approximately 40 db and while this may produce some masking, it appears not to be a significant contribution to the total, since 30 db of noise is required before effective masking can be observed. Noise, then, is probably not a major factor in the masking effect of water-douche masking. Next to be considered is the effect of the mass of the water in the canal. The meatus, during masking, is filled with water completely. Although many other studies have recorded the effect of mass on threshold sensitivity, we used glycerin to fill the canals of both ears in ten subjects. As was to be expected, we obtained a sound field air conduction loss of approximately 30-35 db with no appreciable change in bone conduction

TABLE 7.—MEANS AND STANDARD DEVIATIONS OF AUDIOMETRIC AIR CONDUCTION THRESHOLDS FOR THE POORER EAR OBTAINED WHILE MASKING THE BETTER EAR WITH 80 DB SAWTOOTH NOISE WITH 80 DB WHITE NOISE AND WITH WATER DOUCHE FOR INDIVIDUALS WITH UNILATERAL HEARING LOSS.

	SAWTOOTH NOISE		WHITE NOISE		WATER DOUCHE	
	MEAN DB	STANDARD DEVIATION	MEAN DB	STANDARD DEVIATION	MEAN DB	STANDARD DEVIATION
500 cps	94.5	5.1	92.1	5.1	93.3	4.5
	N 11		N 21		N 6	
1000 cps	95.0	3.7	94.7	1.2	92.5	5.6
	N 11		N 19		N 6	
2000 cps	95.4	2.7	94.7	2.0	91.2	4.2
	N 11		N 17		N 4	
4000 cps	95.6	3.2	94.8	4.9	91.7	4.7
	N 8		N 14		N 3	

measurements. The third factor (or factors) to receive attention is probably related to the fact that the water is not static but in motion. This introduces enough variables that we do not feel confident to enumerate them. We are quite certain, however, that they are operative in the total masking effect.

The masking effect of the three factors of noise, mass and the flow of the water probably differ in significance for testing air and bone conduction reception. In testing for air conduction, the noise plus the mass would not account for all of the masking obtained because the effects of the two are probably not additive. It may be that the two combined produce only 40 db of masking; the total to be accounted for, however, is in the order of 90 db. It appears then, that the conditions set up by the flow of water are responsible for a relatively large proportion of the total masking effect of water-douching for air-conducted sound. In testing for bone conduction the presence of the mass would make no appreciable change in the bone conduction reading, consequently, the noise and the flow of

TABLE 8.—MEANS AND STANDARD DEVIATIONS OF BONE CONDUCTION THRESHOLDS FOR THE POORER EAR OBTAINED WHILE MASKING THE BETTER EAR WITH 80 DB SAWTOOTH NOISE, WITH 80 DB WHITE NOISE AND WITH WATER DOUCHE FOR INDIVIDUALS WITH UNILATERAL HEARING LOSS.

	SAWTOOTH NOISE		WHITE NOISE		WATER DOUCHE	
	MEAN DB	STANDARD DEVIATION	MEAN DB	STANDARD DEVIATION	MEAN DB	STANDARD DEVIATION
500 cps	51.5	5.6	41.4	12.4	54.4	6.2
	N 10		N 21		N 8	
1000 cps	56.5	3.9	56.8	8.3	50.0	6.6
	N 10		N 20		N 8	
2000 cps	56.5	5.5	58.6	5.7	53.8	8.6
	N 10		N 18		N 8	
4000 cps	57.0	4.0	58.1	4.5	55.0	7.1
	N 5		N 8		N 3	

the water would be the significant contributors to the masking effect. The noise would, it would seem, produce little more than 10 to 20 db of masking, yet the total masking effect for bone conduction is close to 45 to 50 db. In both air and bone conduction scores, then, the elements present in water douching other than the noise and mass create a masking effect which may approach or exceed 40 db.

This study has not explored all of the possibilities of water-douche masking. Variations in technique and changes in instrumentation, such as elevating the water source or increasing the lumen of the cannula, may result in increased masking effect. This exploratory investigation suggests that those interested in the problems of masking for clinical purposes might do well to direct their attention away from variations in types and intensities of noise to alternative possibilities which might be less likely to affect the unmasked ear.

At the conclusion of these tests, we should like to mention briefly some of the problems encountered in bone conduction audiometry.

The measurements shown here, particularly those conducted with the subjects experiencing a unilateral hearing loss, point to the necessity for masking when bone conduction is used. Indirectly, they call attention to the importance of obtaining a reading of lateralization by the Weber test, inasmuch as the imperativeness of masking the lateralized ear when the non-lateralized ear is tested is emphasized in these studies. The authors recognize the difficulty in eliciting a true reading of lateralization and realize its practical impossibility when a severe unilateral loss has been present since infancy or has otherwise been of a long-standing nature. The employment of a battery of tests to determine true lateralization is recommended rather than a single application of one stimulator at one frequency. Even with the utilization of masking in the lateralized ear, it is recognized that a true reading of the bone conduction sensitivity in the non-lateralized ear is often impossible. These several points emphasize the need for multiple examination procedures in problem cases and point to the valuable information which speech audiometry affords in some instances.

SUMMARY

A method of masking air and bone conduction reception, using irrigation of the ear canal as the masking technique, is described and applied to a group of normal-hearing individuals and to a group exhibiting unilateral hearing loss. Water-douche masking produces a masking effect in the order of 90 db by air conduction and 45-50 db by bone conduction. The effect is obtained even though noise is not a significant factor in the total masking observed. Though data is incomplete, it may be that water-douche masking may be less likely to result in elevated thresholds in the unmasked ear than high intensity noise masking.

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LVII

MALINGERING

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According to the dictionary, malingering is defined as—"feigning illness in order to avoid duty—as a soldier or sailor."

Dr. Keschner of Columbia University defines malingering or simulation as—"a wilful, deliberate and fradulent imitation or exaggeration of illness. It is usually resorted to by individuals who have sustained an injury which is compensable under the Workmen's Compensation Law."[1]

I would say, "feigning illness for purposes of gain." True malingering does not exist without a suitable motivation. Before I proceed into a discussion of malingering and its discovery, it would probably be profitable to point out the magnitude of the problem in the general population.

A review of the literature discloses that feigning illnesses in general is not uncommon. A closer look will reveal that each type of illness is related to a reward of some kind, usually compensation payments. If the literature is narrowed to discussions of hearing loss cases, one finds very little. At first this may be surprising but, if one looks for the motivation in this type of malingering, he will notice that, until recently, there has been none in the civilian population. On the other hand, if one turns to the military services, he finds the motivation in the form of exclusion from all duty, or exclusion from especially distasteful duties, and monetary compensation with retirement.

Such motivation makes it worthwhile to feign a hearing loss, with the result that 25 to 30 per cent of all hearing loss cases considered in the military forces must be treated as suspected malingerers.

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Director, Audiology and Speech Correction Center, Walter Reed Army Hospital. (At present, on leave of absence.)

This tendency to simulate illness is apparently deeply rooted in the human. Which one of you can truthfully say he has never "played sick" to stay out of school at one time or another? Wilful simulation is certainly not confined to man. What about the quail who feigns a broken wing to draw attention away from her brood, or the cat who feigns sleep while the mice play, and any number of other examples. I believe it is safe to assume that on the basis of the military records that malingering will be a serious problem among industrial workers when compensation laws furnish the proper motivation. This has been true in other forms of compensable disease and hearing loss should be no exception.

Probably the most important but least remembered facet of the malingering problem is the part played by illness of phychogenic origin. True, the malingerer may be classed as a psychogenic of a sort, a misfit or maladjusted personality who shirks his social responsibility and refuses to maintain a strictly honest attitude.

I believe simulation of illness can be thought of as malingering, neurashthenia, neurosis, psychogenic overlay and hysteria. If I may be permitted to use abstract and poorly defined terms, the malingerer is a psychogenic who consciously and usually dishonestly feigns illness, while the neurasthenic, the neurotic, the individual with a psychogenic overlay and the hysterical person simulate illness subconsciously and differ from each other only in magnitude. I am sure that many individuals with a psychogenic overlay or hysteria began as malingerers but eventually came to believe in their own simulation, possibly through a process of auto-suggestion. Such simulation is, therefore, no longer wilful or dishonest and thereby cannot be classed as malingering.

I prefer to include all hearing losses other than organic under the general term—functional hearing loss. This term carries no connotation of dishonesty and can be used freely without fear of arousing unnecessary antipathy in the suspected patient. Malingering is a serious charge. The burden of the proof rests with the accuser and, believe me, proving malingering in hearing loss cases in the absence of an admission is most difficult with our present testing methods. It is because functional hearing loss can be wilful, deliberate or conscious and subconscious, if you will, that I am very careful before branding a patient as a malingerer. Unless wilful intent to defraud can be shown by a voluntary or an inadvertent admission, maling-

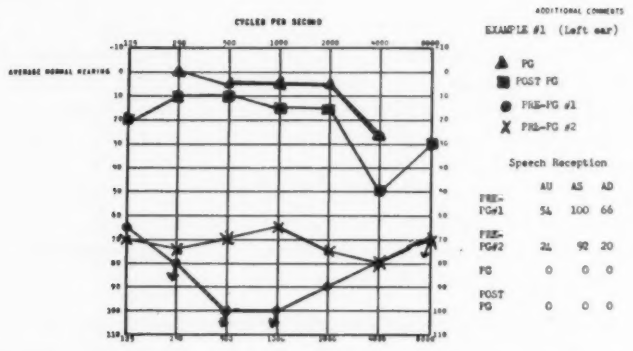

Fig. 1.—PG=Psycho-galvanic test results. Post PG=Threshold audiometry subsequent to the psychogalvanic. Pre PG=Threshold audiometry prior to the psycho-galvanic.

ering cannot be proven. With this in mind, I will proceed to discuss some old and some new testing techniques.

Tests for the discovery of malingering are almost innumerable, even in the field of otology. I shall not spend time enumerating or evaluating these tests, suffice it to say that only very few of them are still in use. Of those tests known prior to World War II, the Stenger for unilateral loss, and the Lombard for either unilateral or bilateral loss, remain. Each of these is based on a fundamental principle of psychoacoustics—the effect of masking. It is not my purpose to discuss either of these tests as to technique or application. They are well known to all of you. One of the interesting results of the development of electronic auditory test equipment is the modification of the Stenger and Lombard tests as presently used.

Originally the Stenger test was performed with matched tuning forks controlled by varying the distance of each from the subject's ear. This appears clumsy and crude when compared to the modern Stenger as performed with two oscillators controlled by calibrated attenuators making it simple to use several matched tones whose loudness is controlled by a simple twist of a dial. The principle of the Stenger test has still further been varied to encompass speech. I expect many of you have seen speech equipment arranged to present a

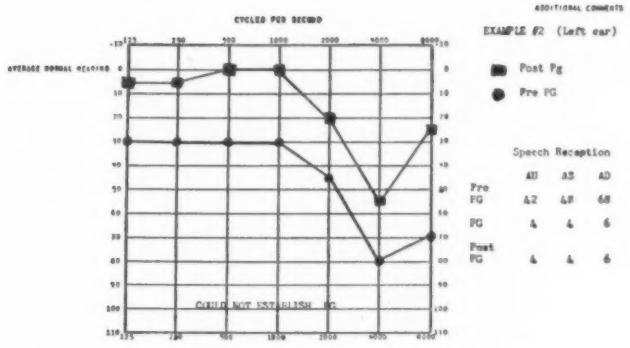

Fig. 2.—Post PG=Threshold audiometry subsequent to the psycho-galvanic. Pre PG=Threshold audiometry prior to the psycho-galvanic.

story to the subject as the stimulus is switched from ear to ear at the will of the operator. During World War II, the Services modified this to include a story about a soldier, a marine, and a sailor. Certain acts were attributed to each of these in such a way as to comprise a complete story whether the subject was aware of one or all three of the men. As the test proceeded, however, no mention of a sailor was made in any but the alleged poor ear. When the subject is asked to recount the story, any mention of the sailor is evidence of hearing in the "poor" ear. This test has pointed a suspicious finger at many a unilateral malingerer.

With the acceptance of the pure tone audiometer as the best means of testing auditory acuity, there is a commonly accepted feeling among many physicians that the audiometer itself is an infallible test of malingering when repeated tests are carried out at varying time intervals. "Because," it is claimed, "no one can repeat a pure tone threshold with any degree of accuracy if he is simulating a hearing loss."

In my experience this is not entirely true. I have seen many patients or even experimental subjects reproduce audiograms within the technical limits of the modern audiometer on many occasions and at varying time intervals. This is not too difficult when the pure tone audiometer alone is used. It is relatively easy for many

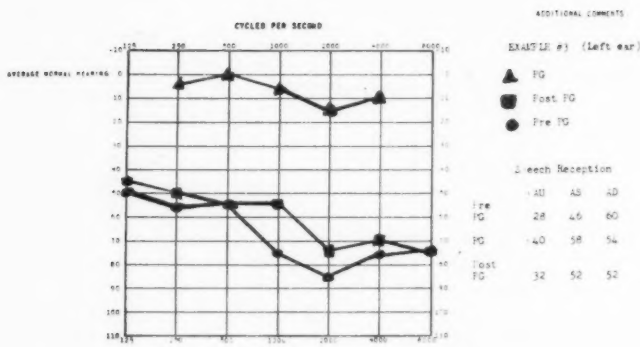

Fig. 3.—PG=Psycho-galvanic test results. Post PG=Threshold audiometry subsequent to the psycho-galvanic. Pre PG=Threshold audiometry prior to the psycho-galvanic.

patients to establish a loudness level under test conditions and not respond until this level is reached, thereby simulating hearing losses of various amounts. It is frequently very difficult to break down this self-appointed loudness level by routine audiometry no matter how many times it is repeated. As a matter of fact, it is many times fixed more firmly by frequent pure tone audiometry.

Prior to World War II, the malingerer was discovered more by trick than by formal test. The unilateral malingerer has always been relatively easy to uncover with the classical Stenger test, but the man who simulates a severe bilateral hearing loss is still a very difficult problem.

As the field of electronics advanced, it became evident that modern communications demanded more exact knowledge about "hearing" and particularly methods of testing hearing for speech. The development of speech reception tests soon followed and the otologist was given a new instrument in his fight against the malingerer. Two important developments followed which were to be very significant to the discovery of malingering.

The first of these was the pure tone-speech reception relationship. It was soon noticed that, in general, the average threshold of 500, 1000 and 2000 cps agreed with the speech reception threshold

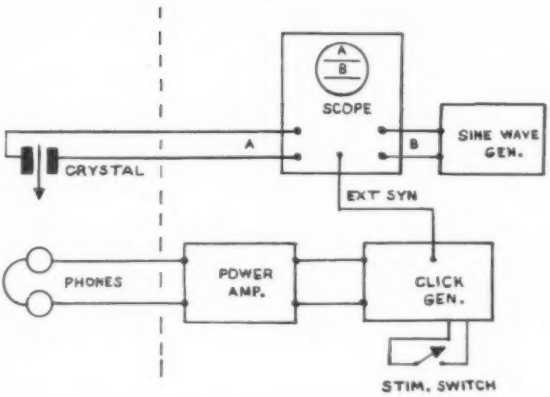

Fig. 4.—A block diagram of the "eye blink" test equipment.

as obtained with the Spondee test lists, within 10 to 12 db or better in all valid hearing tests. Further, that spurious results were almost invariably accompanied by a serious discrepancy in the pure tone-speech reception relationship. In my experience this discrepancy is the most important single indication of functional aberration in a hearing test. At present the Army, Air Force and Veterans' Administration use this relationship as a check on the validity of their hearing tests. For example, when a service man reports that he has a hearing loss, he is tested at an Army Hospital where an auditory screening center is maintained. This center is equipped with both pure tone and speech audiometers. If the pure tone and speech reception thresholds are within 10 to 12 db of each other and the loss is 30 db or more, the man is sent to the Audiology Center for auditory rehabilitation. If there is a discrepancy greater than 10 to 12 db in the pure tone-speech reception relationship, he is tested a second and third time. If these repeat tests demonstrate the same or a greater discrepancy the man is considered to have a functional element in his hearing loss and he is sent to the Audiology Center for further study.

In the Veterans' Administration, the relationship is applied to the initial examination for disability rating. If the pure tone-speech reception threshold relationship is within 12 db on two successive

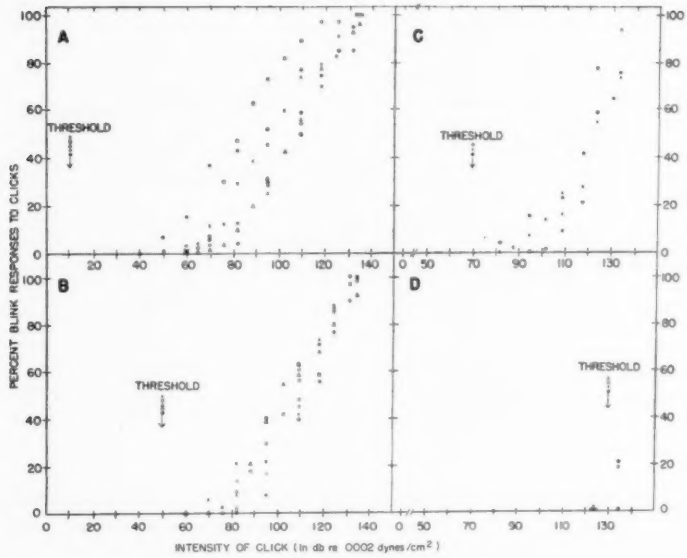

Fig. 5.—The frequency of blinking (ordinate) plotted against the intensity of stimulation. Each point represents the percentage of times a click of the indicated intensity produced a recordable eyeblink. Monocular recording, binaural stimulation. A, Normal subjects; B, Subjects with 40 db hearing loss to clicks; C, Subjects with 70 db loss; D, Subjects totally deaf by all tests.

tests they are considered valid; otherwise the veteran is studied for a possible functional hearing loss. This method has been used for more than two years and, up to now, there are no indications for a change.

I believe the pure tone-speech relationship is effective in disclosing a functional hearing loss because a speech signal is a transient sound and therefore is difficult to match in loudness against an established spurious pure tone loudness level. This results in a discrepancy when the malingerer is tested by pure tone and speech.

The second development and one of the most interesting tests for functional hearing loss was developed by Doerfler and Stewart[2]

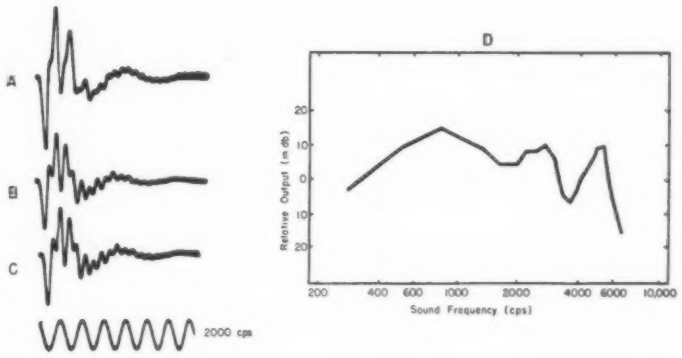

Fig. 6.—Acoustical output of the earphones as recorded by a condenser microphone in a 6 cc. coupler.

A. Oscillogram of the output of one of the earphones used: The standard 0.3 msec. square wave is attenuated 20 db from maximal output.

B. Output from the second earphone with the same input as in A.

C. Output of earphone B at O db attenuation after reduction of oscilloscope amplifier gain by 20 db.

D. Fourier transform of B (23.5 harmonics) showing relative acoustical output of the click at various frequencies.

while working with service men at one of the Army's Aural Rehabilitation Centers. It is now known as the D-S Test. This test is designed to break down the established spurious loudness level by superimposing a specially designed noise over a speech signal. By varying the relationship between the two signals, the loudness level "yardstick" is disturbed and the functional loss subject varies from the normal. The D.S. test has proved very useful in building the case against the malingerer in the Armed Forces. I believe the D.S. Test should be a routine one in all cases where the motivation may promote the desire to malinger.

Naturally, the problem of malingering brings up the subject of objective hearing tests, but they will result in no exact method of differentiation unless they enable us to separate malingering from psychogenic overlay. The test we think of first, of course, is the psychogalvanic used in the Armed Forces late in the war and later publicized and simplified by Bordley, Hardy and Richter.[3] The

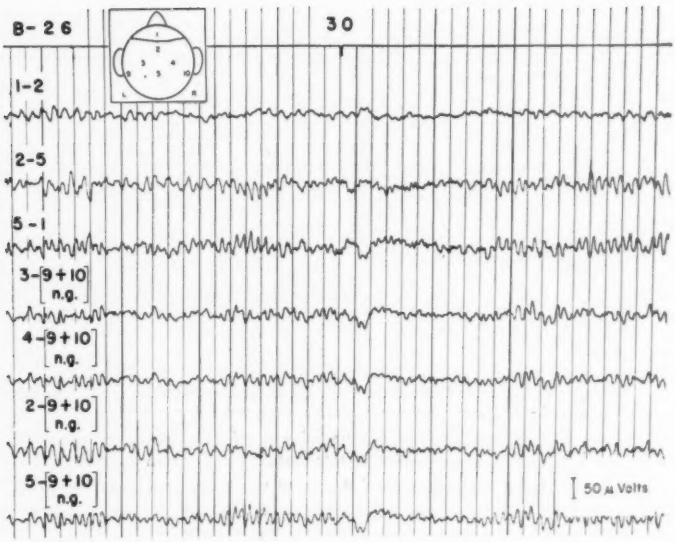

Fig 7.—Brain wave changes to a click in a waking subject. A transient deflection and disappearance of alpha activity follow the single click indicated by the stimulus marker in the uppermost channel. The vertical lines are separated by 200 msec. A positive voltage on the first grid of each channel results in a downward deflection of the pen. The designation (9 + 10 n.g.) refers to the reference electrode, which is connected to both mastoids and ungrounded. The stimulus strength (30) is about 40 db above the threshold for persons with no hearing loss.

psychogalvanic test is used routinely in the Army Audiology Center in all cases suspected of having a functional hearing loss. In my experience, the psychogalvanic, or P. G., is not a test for malingering but can be used to help in its discovery.

Figures 1, 2 and 3 ably demonstrate this. These audiograms indicate only that the patients have a functional hearing loss, but do not brand this loss as a wilful or deliberate attempt to simulate a hearing loss. They serve only to make the tester aware of the possibility of malingering and that he must resort to any means at hand to obtain an admission of guilt on the part of the patient. Actually, the P. G. is not really an objective hearing test. By definition, an

objective test is one which requires no active response. That is to say, no voluntary or even conditioned response. The P. G. is a conditioned response and therefore probably not strictly an objective test.

In my search for a simple, dependable auditory response with no apparent effort on the part of the subject, I enlisted the help of the department of neurophysiology of the Army Medical Service Graduate School.

Probably one of the most basic auditory reflexes we know is the startle response. One of the components of this basic response is the "eye blink." The "eye blink" is well known to the pistol expert and, although the expert has fired many rounds, the "eye blink" reflex never really disappears. On the basis of this, we decided to try it as a hearing test. Figures 4 and 5 illustrate some of the results.[4] Figure 4 is a block diagram of the equipment used in the "eye blink" test. A crystal phonograph pick-up is placed in contact with the upper eyelid by a blunt needle. Any movement of the lid is traced on an oscilloscope.

In order to eliminate recording voluntary eye blinks, a 1000 cps tone is traced across the oscilloscope timed to synchronize with the stimulus presented to the ear. A calibrated click is used as a stimulus and reduced in sound pressure until the eye blink is no longer picked up. Figure 5 indicates the per cent responses in cases with normal hearing and increasing hearing losses from A to D.

Auditory responses recorded by the electroencephalograph have proven disappointing in general. The "startle response" and the "arousal response" are well known to EEG technicians, but neither of these is very close to the auditory threshold.

A series of experiments were conducted at the Audiology Center at Walter Reed, and Figures 6, 7, 8 and 9 clearly demonstrate the results. None of the changes noted are specific to the auditory stimulus but, in these experiments, occurred as a result of an auditory stimulus.[5]

Recently, 1950 and 1951, B. S. Lee reported an experiment called the "Effects of Delayed Speech Feedback"[6] or "Artificial Stutter."[7] The application of these experiments to functional hearing loss cases was an obvious result.

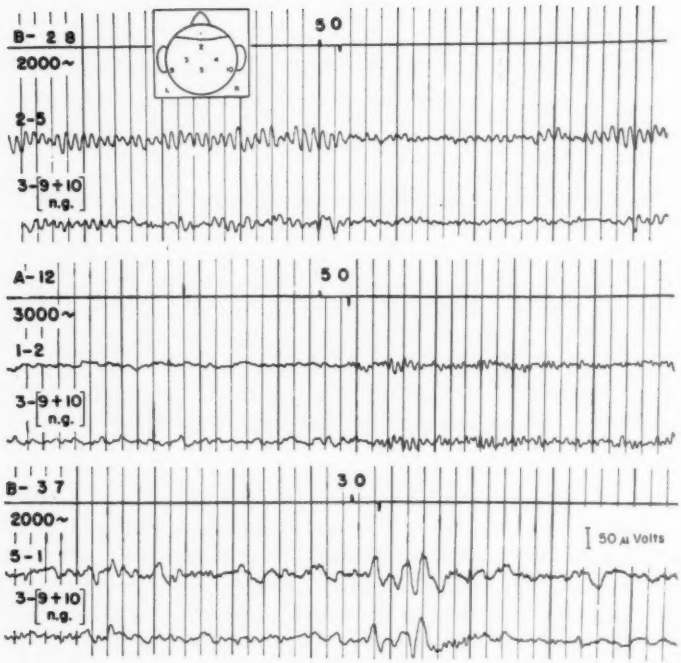

Fig. 8.—Some effects of tone bursts on the EEG. The top line in each record shows the frequency used and its duration (onset upwards, off downwards). Other details as in Figure 7.

A. Upper record: Disappearance of alpha activity following a tone burst.

B. Middle record: Partial return of the waking pattern following a tone burst in a drowsy subject.

C. Lower record: A form of the K complex following a tone in a drowsy or lightly sleeping subject.

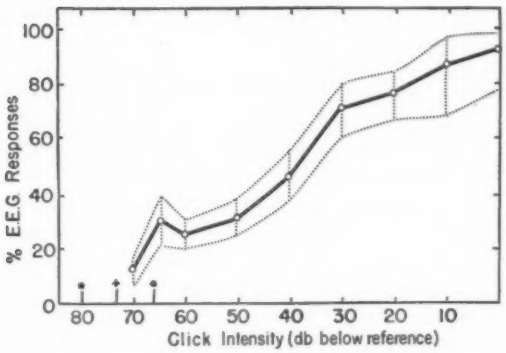

Fig. 9.—The relation between click intensity and percentage of EEG responses for 10 normal subjects (solid curve). Each point is calculated from the total responses obtained from all subjects. The dotted lines indicate the confidence limits ($p = 0.05$) of these data. The subjective click threshold for each of the subjects fell within the limits indicated by the asterisks. The average subjective threshold is indicated by the arrow.

All of us know that speech is monitored by hearing and that if this "feedback circuit" is broken in any way the monitor is no longer in control. This "delayed speech feedback" test is one of the few tests by which we are able to break into a physiological "feedback circuit." If you will remember, I have stated that in order to objectively prove malingering we must have a test which will differentiate malingering from psychogenic overlay. When the speech feedback test came to my attention I regarded it as a possible technique which would do just that.

The psychogalvanic, eye blink and electroencephalograph are what I consider lower order auditory tests. That is to say they test lower order neural mechanisms and, if positive, indicate neural activity which includes the auditory system from the standpoint of continuity of transmisson of a sound stimulus.

A negative result, however, does not necessarily indicate a break in the auditory system. The first two are reflex type mechanisms and may therefore be completed without the need of higher cerebral centers. Similarly the EEG indicates auditory activity by nonspecific

brain wave changes. So far none of these tests has denoted changes in responses which indicate a difference in neural activity between a conscious and a subconscious block.

By definition the malingerer can hear and admits it to himself but not to others. On the other hand, the psychogenic does not admit hearing even to himself. It we assume that the psychogenic has a central block which shuts out hearing by higher center controls it seems logical to assume that the malingerer is exerting a higher center control also; but through different neural pathways which can be interrupted by certain basic stimuli. For example, if the delayed speech feedback circuit test is applied to a case with a psychogenic overlay who, according to our assumption, has a high order neural block, the delayed speech should not confuse him; but, on the other hand, the malingerer should be confused because he is unable to control the effects of the delayed speech on his monitoring feedback circuit.

It is too early to give any positive results obtained in our studies of the delayed speech test, but I am certain that we are on the right track in our search for a malingering test.

SUMMARY AND CONCLUSIONS

Malingering hearing loss, as defined, cannot be demonstrated by test alone. In order to differentiate it from the hearing losses of psychogenic origin one must obtain, directly or indirectly, an admission of intent to defraud.

Several tests have been discussed, and I have demonstrated that each of them will indicate the difference between a functional and an organic hearing loss, but so far none has divided the functional losses into malingering and psychogenic overlay. In my opinion, the tests merely add weight to the case against the malingerer and the result depends upon who is more clever, the doctor or the patient.

1136 W. 6TH ST.

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LVIII

OBSERVATIONS FROM A CONTROLLED STUDY ON THE EFFECT OF NASOPHARYNGEAL IRRADIATION IN A GROUP OF SCHOOL AGE CHILDREN

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In 1948 a five-year joint research project was undertaken by the Johns Hopkins School of Hygiene and Public Health, the Department of Otolaryngology of the Johns Hopkins School of Medicine, the Department of Health and the Department of Education of the City of Baltimore. It was supported by grants-in-aid from the U. S. Public Health Service. The object of the project was to carry out a controlled study in the public schools of Baltimore to determine: (1) the efficacy of nasopharyngeal irradiation for the reduction of lymphoid tissue in the nasopharynx; (2) the changes taking place in hearing acuity following nasopharyngeal irradiation; (3) the effects of puberty on lymphoid growth and hearing acuity; (4) the efficacy of modern diagnostic techniques in predicting hearing loss in a school-population, and (5) practical methods for carrying out a conservation of hearing program which could be adapted to a municipal school-health program.

A total of 5428 children in the third grade, averaging 8.5 years of age, were screened in 56 public schools during the winter of 1948-49 and the fall of 1949. These schools represented a cross section of the population both racially and economically. Auditory screening was done with threshold audiometry for four tones (1024, 2048, 4096 and 9747); and the ears, nose and throat of each child were

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examined at the same time. The criteria for admission to the preselection group was hearing impairment of 15 decibels or more in two tones, or 20 decibels or more in one tone. Eleven hundred and seventy-one children were thus selected. The hearing acuity of this group was again tested with an audiometer, this time for eight octaves from 128 through 9747 cycles, and a second examination was made of the tympanic membranes and upper air passages. The nasopharynx and the pharyngeal orifice of the eustachian tubes were examined with an electric nasopharyngoscope. The same criteria for hearing impairment were employed. The re-examination of these 1171 children resulted in the selection of 582 for the study group.

The children in the study group were divided by random alternation into two groups, one of which was to receive nasopharyngeal irradiation, and the other to serve as controls. The nasopharynges of the children in the treated group were irradiated 12 minutes on each side on three occasions with the 50 mgm anhydrous radium sulfate applicator. In all cases the interval between treatments was not less than two weeks. The controls were handled in precisely the same way as the treated group, with one exception. The applicator used in this group was a blank containing no radioactive substance. The applicators loaded and empty were color-coded and their contents were not known to the doctors giving the treatments. During the succeeding four years, both treated and control groups were re-examined twice each year. These follow-up examinations included an eight tone audiometer study, a complete ear, nose and throat examination, including electric nasopharyngoscopy. A second series of three irradiations was given to 36 children on the recommendation of the field teams, but not until one year had elapsed following the completion of the first series. Of these, 19 were in the control group and were treated for the second time with blank applicators. In the fifth year of the study as many of the original 5428 children as could be found were re-examined to determine changes in hearing and to note any gross changes that had taken place in lymphoid tissue. A total of 2753 (56.8 per cent of the original group) were resurveyed.

FINDINGS

After five years 385 children of the original 582 in the study group had undergone every essential examination and treatment. Of these, 193 children (307 affected ears) were treated, while 192 children (284 affected ears) were controls. Six children (12 ears) were

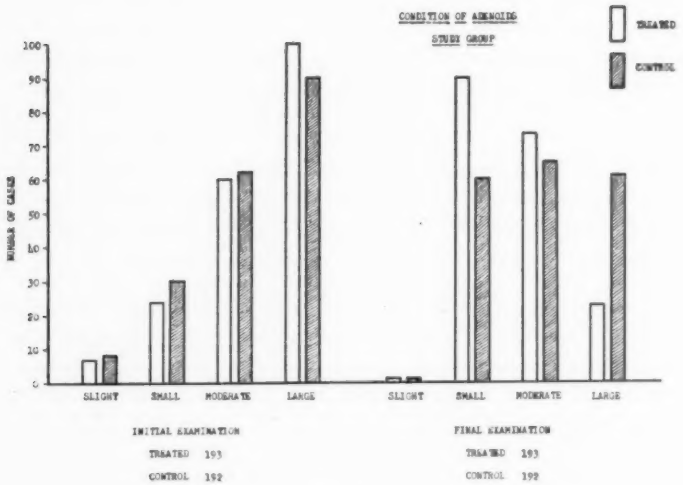

Fig. 1.

taken out of the study because of serious progressive loss of hearing. This was done according to an agreement with the City Health Department not to jeopardize the future hearing of any child. The remaining 185 children lost from the original study group were dropped because of missed examinations, transfer to outside schools, truancy, and the like. Observations made on the survey group and the study group were entered on IBM cards, and all pertinent statistical analyses were carried out by the University's Computing Laboratory. Over 500,000 items were coded for study.

The questions of greatest interest to be considered in analyzing the clinical data accumulated from the study group are: (1) the effect of nasopharyngeal irradiation on adenoid masses; (2) changes that can be observed around the orifices of the eustachian tubes following irradiation of the nasopharynx; (3) changes that take place in hearing acuity following irradiation of the nasopharynx; and (4) the effect of puberty on the foregoing classifications as observed in the control group.

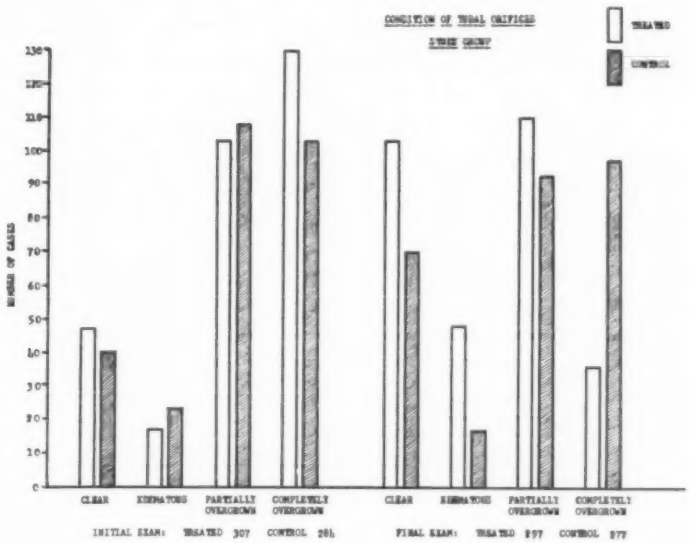

Fig. 2.

Figure 1 shows the changes taking place in the nasopharyngeal adenoid masses during the five-year period in both the treated and control groups. Both categories show improvement. The greatest change takes place in the treated group, shrinkage being most noticeable in the first three years, the control group shows most improvement in the fourth and fifth years, or about the time of puberty. It will be noted that appreciable masses of adenoids remain in 96 children of the treated group; this would strongly imply that irradiation should not displace surgery for the removal of large airway-obstructing masses of adenoid tissue.

Figure 2 summarizes the changes observed around the eustachian tube orifices in both treated and control groups during the study. The change in status of complete overgrowth from 130 to 36, and the increase in the number of clear tubal orifices from 47 to 103 in the treated group, clearly outweighs the changes seen in the control

TABLE 1.

STATISTICAL SURVEY OF STUDY GROUP (591 EARS)

307 EARS TREATED 284 EARS CONTROL

	INITIAL TEST		FINAL TEST				
FREQUENCY	TREATED MEAN	CONTROL MEAN	TREATED MEAN	CONTROL MEAN	GAIN TREATED	GAIN CONTROL	DIFFERENCE TR. > CON.
128	15.10	13.39	6.27	6.13	8.83	7.26	1.57
256	18.04	16.40	7.98	7.82	10.06	8.58	1.48
512	14.82	13.09	4.83	4.11	9.99	8.98	1.01
1024	12.36	11.52	3.62	3.80	8.71	7.72	1.02
2048	10.17	8.52	3.35	3.37	6.82	5.15	1.67
4096	12.54	10.27	4.49	5.13	7.55	5.14	2.41
8192	20.17	17.87	6.78	6.00	13.39	11.87	1.52
9747	21.71	20.20	8.75	9.33	12.96	10.87	2.09

group. It would seem reasonable to believe that the completely overgrown eustachian orifice offers a greater potential hazard to the middle ear than a status that can be described as clear.

Table 1 presents the composite picture of the hearing acuity of the treated and control groups. The gains (in decibels) of the treated over the control groups are expressed as mean values. There is a uniform small gain of the treated over the control group for all octaves; it is however too small to be statistically significant. The most striking thing in this table is the general improvement from initial to final audiograms in both groups.

In analyzing the hearing of the 591 ears under consideration, no statistically significant difference between the treated and control groups was found where there were mild losses for either one or two tones.

Two hundred and twenty ears showed losses of 25 decibels or more for two or more of the eight tones in the original selective audiogram (Table 2). These ears were subdivided according to hearing loss, into three groups: (a) low-tone losses, (b) high-tone losses, and (c) impairment in both high and low ranges. This table shows the changes found in these three categories after five years. While the low-tone-loss group (a) shows a slightly better incidence of improvement than does the high-tone-loss group (b) these changes are not statistically significant. The changes found in the group with both high and low-tone ranges depressed (c) the classical conductive type are of a different order. The improvement seen here in both treated and control groups is considerable, but that of the treated group is far greater than that of the control group (Fig. 3). The six children (12 ears) which were dropped from the study group because of serious progressive deterioration of the hearing were all from the control section of this last category (c). If they had been retained the number of children in control and treated groups would be about equal, and the gain in hearing of the treated group over the control group would be even greater.

In the fifth year, 2753 children of the original 5428 screened and found to have normal hearing were resurveyed. An ear, nose and throat examination was carried out and the four tone audiogram was repeated. The average age was 13½ years. This group represents children from all the 56 schools originally surveyed. From this resurvey, 118 children were found to have hearing thresholds of 15

TABLE 2.

CHILDREN WITH MODERATELY IMPAIRED HEARING (2 OR MORE TONES AT 25 DECIBELS OR MORE) IN (A) THE LOW-TONE RANGE (128-1024 CYCLES), (B) THE HIGH-TONE RANGE (2048-9747 CYCLES), OR (C) BOTH RANGES; DATA INCLUDES MEANS OF THE GAINS (INITIAL AGAINST FINAL TEST), CORRELATED INDIVIDUALLY, AND THE DIFFERENCE BETWEEN MEANS OF GAINS, TREATED CONTROL.

	A IMPAIRMENT IN LOW RANGE			B IMPAIRMENT IN HIGH RANGE			C IMPAIRMENT IN BOTH RANGES		
	TREATED (26)	CONTROL (26)		TREATED (49)	CONTROL (47)		TREATED (43)	CONTROL (29)	
FREQUENCY	MEAN GAIN	MEAN GAIN	DIFFERENCE TR. > CON.	MEAN GAIN	MEAN GAIN	DIFFERENCE TR. > CON.	MEAN GAIN	MEAN GAIN	DIFFERENCE TR. > CON.
128	21.98	17.98	4.00	4.49	3.46	1.03	21.69	13.62	8.07
256	20.48	18.65	1.83	5.82	6.17	-.35	23.31	15.95	7.36
512	15.77	16.06	-.29	7.96	8.62	-.66	24.83	14.05	10.78
1024	13.07	11.15	1.92	7.24	7.18	.06	22.44	14.74	7.82
2048	5.19	5.67	-.48	7.14	5.48	1.66	22.56	13.79	8.77
4096	5.19	3.08	2.11	9.23	6.22	3.01	24.53	17.59	6.94
8192	8.56	5.87	2.69	19.43	21.10	-1.67	27.03	21.29	5.74
9747	4.23	3.94	.29	19.18	18.19	.99	26.22	17.33	8.89

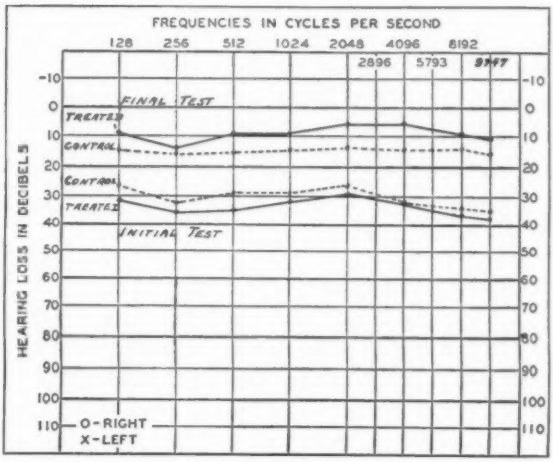

Fig. 3.

decibels or more in two tones or more, or 20 decibels or more in one tone in one ear. It means that only 4.2 per cent of the group would meet the original criteria for preselection and reexamination with an eight tone audiogram and a complete ear, nose and throat and nasopharyngoscopic examination to determine their eligibility for admission to a study group. This compares very favorably with the 21.5 per cent at the time of the original survey. Those children reexamined showed 20 per cent less lymphoid tissue on the posterior pharyngeal wall at the end of five years.

A significant change in the hearing of this resurveyed group of 2753 children was found to be average improvement of approximately three decibels at 1024 cycles (Fig. 4).

DICUSSION

The problems considered in this five-year study were as follows: (1) to determine the efficacy of nasopharyngeal irradiation for the reduction of lymphoid tissue; (2) to study the changes that take place in hearing acuity following irradiation of the nasopharynx; (3) to investigate the effects of puberty on lymphoid growth and

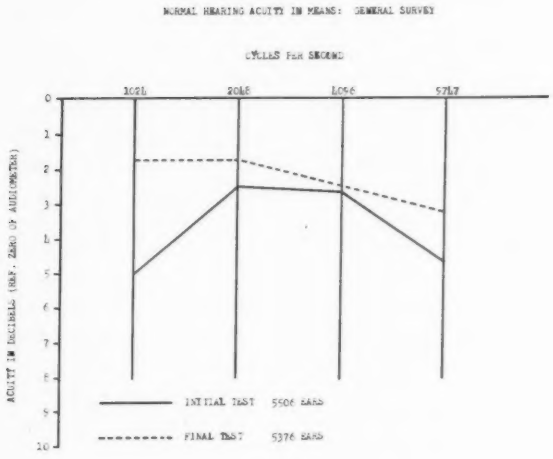

Fig. 4.

on hearing acuity; (4) to determine the efficacy of modern diagnostic techniques for predicting hearing loss in a school population; and (5) to develop procedures for screening a school population and for carrying out a conservation of hearing program which would be feasible for adaptation into a school-health program.

There is unmistakable evidence that nasopharyngeal irradiation reduces lymphoid tissue to a remarkable degree. The children irradiated showed reduction not only in the mid-line adenoid masses but especially in the lymphoid overgrowth and edema around the eustachian orifices. Most of this reduction took place in the first 18 months after irradiation, but its effects persisted until the end of the program. Decrease in the size of lymphoid tissue was noted in the control group during the fourth and fifth years; this suggests puberty as a causative factor for the change. Reexamination at the end of the five year period of 2753 of the 5428 children in the original group confirms the impression that puberty brings about changes in lymphoid tissue in the upper air passage. In this group the nasopharynx was not examined with a nasopharyngoscope, but judging from the notes of the first examination it is estimated that there is approx-

imately 20 per cent less visible lymphoid-tissue on the posterior and lateral walls of the pharynx than there was five years previously. Lymphoid overgrowth around the eustachian orifices, however, showed little if any improvement in the non-irradiated subjects. These findings show that nasopharyngeal irradiation is a satisfactory method to reduce lymphoid overgrowth around the eustachian tube orifices.

In the study group as a whole, improvement was found in the hearing acuity of both the treated and control children. The gain was always most marked for the treated children whose hearing loss was a conductive type affecting all tones. These findings substantiate the reports of Crowe,[1] Guild,[2] Bordley,[3] Canfield,[4] Proctor,[5] Mikell,[6] and others.

Improved hearing in the control group can be accounted for only by factors such as puberty, learning (with regard to listening in audiometric testing), and improved nasopharyngeal hygiene.

These findings point up and may explain a divergence of opinion concerning the management of children with a conductive type hearing loss. Some clinicians have held that they have seen the hearing improve in children who were not irradiated, and have doubts about the value of irradiation. Their contention regarding the improvement of hearing is correct. The present study, however, demonstrates that in children suffering from hearing loss of eustachian tube origin irradiation of the nasopharynx has an important additive therapeutic effect beyond that related to maturation.

No evidence of trauma relatable to irradiation of the nasopharynx was observed in any of the treated group.

In the general survey group it was noted that acuity for the tone 1024 cycles had improved during the five years of observation. This was the lowest tone used in our four tone screening tests, and this increased acuity is in agreement with the suggestion made by Guild that physiologic improvement for the low tones occurs in children with normal hearing as they mature. The evidence of our study suggests that this improvement in hearing takes place at puberty. This may be associated with the change in the condition of the lymphoid tissue; no other finding is so consistently relatable.

The criteria we selected for screening were more stringent than those usually employed in hearing surveys. The reason for this was our desire to determine what proportion of this school-age population

could be preselected. Only 4.2 per cent of the general group re-examined after five years exhibited deviation from normal hearing (in comparison with 21.5 per cent of those originally surveyed). This shows that most of the children with potential hearing impairment were successfully preselected from the school population by the methods of examination we employed.

The fact that this study was carried out successfully is clear evidence of the feasibility and effectiveness of inter-agency cooperation in a school-health program.

For many years there have been critical discussions about nasopharyngeal irradiation, its effect on the growth of lymphoid tissue, and on hearing impairment of the conductive type, resulting from eustachian tube obstruction in children. The possible effect of puberty on lymphoid growth with its secondary influence on hearing impairment has also been of great interest. Questions such as these could only be effectively answered by a carefully controlled, long-term study. It is hoped that this report will contribute some definitive answers to these questions and will stimulate further interest in conservation of hearing programs for children.

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LIX

EPIDERMOID CARCINOMA OF THE TEMPORAL BONE

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Epidermoid carcinoma of the temporal bone is not a pleasant story with a happy ending. My observations concern seven patients, afflicted with this disease, seen during the last six years, who comprised 63.63 per cent of the 11 patients found to have malignancy of the temporal bone. Of the other four, two had basal cell carcinoma, and two had neurogenic sarcoma. There were two consistent factors, the histological findings, and the poor results of treatment. Inasmuch as I am not a cancer doctor, all of these patients were seen, also, by doctors specializing in cancer, and the operations were done by them, by me, or by us. Radiation therapy was administered under direction of a radiation therapy specialist. Cases of epidermoid carcinoma of the temporal bone do not follow an exact pattern.

CASE 1.—Mr. W. C. S., aged 42 years, a medium small, healthy appearing man, first had pain in and below the left ear for six months, and facial paralysis on the left side for one month before he was first seen in July, 1948. His was a small lesion lying flush with the floor of the external auditory canal close to the drum membrane. Roentgenograms revealed the left mastoid cells to be cloudy without bone destruction. One month later, he was operated upon through an incision made between the left tragus and the rest of the pinna. The floor of the external auditory canal, annulus tympanicus, and middle ear was removed, together with the anterior part of the mastoid process, the adjacent soft tissue inferior to the external auditory canal, and the facial nerve between the stylo-mastoid foramen and the parotid gland. Although tumor tissue was found around the facial nerve, none was found of the facial nerve. During the next

Due credit and appreciation for their consultation and aid is given Doctors R. Brown, W. Bryan, S. Krantz, E. Scarborough, C. Stewart, and S. Wilkins, of Atlanta.

Cases 1 and 3 operated upon by members of Winship Clinic, Emory University Hospital.

week, he received 1600 r of deep x-ray therapy. His pain became much less pronounced. Ten months later, because the left ear had not quit draining, he was reoperated upon through the same incision. Tumor was found in the soft tissue of the neck under the temporal bone, some of which was removed. Twelve gold radon seeds (1596 millicurie hours) were inserted into the tumor area. February 3, 1950, eight months after the last treatment, he complained of dizziness, difficulty in focusing his eyes (there was no extraocular muscle paralysis), and pain in the right upper arm. X-ray findings were consistent with malignancy of the upper end of the right humerus. There was no further pain in the ear; the dizziness continued; there was a small amount of discharge in the left external auditory canal from an area of denuded bone. Repeated temporal bone x-rays were inconclusive for bone destruction. He died a year and a half later (three years from the onset of disease) of generalized metastases.

CASE 2.—Mrs. C. L. V., aged 50 years, stated that her right ear had been draining a very foul discharge as long as she could remember; however, there had been pain for only "a few months." Found on examination, were extremely foul discharge, postauricular swelling, and "granulations" in the middle ear. By roentgenography, there was almost complete destruction of the mastoid process. There were no palsies. She was operated upon through a postauricular incision. Malignant tissue was found to have replaced the bone of the mastoid process, and there was extensive middle fossa dura involvement. No attempt was made to resect the dura. The operation seemed to stimulate the growth of the tumor. The radiologist looked with disfavor upon giving radiation therapy because of the affected dura. Her course downhill was rapid, her pain was constant and terrifying. She died four months to the day, from the date of the initial examination.

CASE 3.—Mrs. A. E. H., aged 51 years, sister of a prominent dentist, could state with certainty that, prior to June, 1951, she had had no ear trouble in at least 33 years. When she was first examined, in August, 1951, two months after the onset of pain in the right ear, "granulations" were seen arising from the floor of the right external auditory canal. The middle ear appeared normal; the hearing was good; but, by x-ray examination, there could be seen an area of suspicious bony breakdown in the anterior part of the mastoid process below the external auditory canal.

Operation was carried out through a Y-type incision, the two upper limbs passing in front of and in back of the pinna, and the lower part of the Y passing down the anterior border of the sternomastoid muscle to the junction of its middle and upper thirds. The auricle was turned up. The inferior two-thirds of the external auditory canal, the floor of the middle ear, and the anterior portion of the mastoid process, were removed. An upper neck dissection was done.

The operative site healed quickly, but the patient never became free of pain. Three months following the operation, which was six months after the first symptom, there was extensive regrowth of tumor. Thirty-three hundred r of x-ray therapy was administered. From the beginning, her progress had been anything but satisfactory, and she elected not to have further treatment. She died one month later. Her total known duration of illness was seven months.

Case 4.—Mrs. E. G. J., 33 year old doctor's wife, had never known of personal ear trouble, except for itching in both ears. In the early part of 1952, she paid little attention to some discomfort in the left ear; but, one day in May, 1952, while she was taking her children to their doctor for routine checkups, she had such a severe pain in the left side of her neck, just below the ear, that she was forced to return home before making the professional call. Pain was constant and progressive, thereafter. A few days before her initial examination in September, 1952, she thought that the left drum membrane ruptured spontaneously. She was having such severe pain in her neck, below the mastoid bone, that she could not turn her head; such severe pain in the temporomandibular joint that she could scarcely open her mouth; and such severe pain in her throat that she preferred not to eat solid food.

On examination, the left malleus, incus and drum membrane were not present. A small amount of clear fluid was seen in the middle ear, and in the external auditory canal. In the region of the promontory, there was white, glistening tissue which did not resemble cholesteatoma. There was no fungating mass to be seen in the ear. There was swelling in the neck below the mastoid tip. Roentgenograms revealed extensive destruction of the inferior aspect of the petrosa, but there was no evidence of destruction of the bone of the mastoid process.

Fig. 1, Case 4.—(Preoperative) X-ray taken at time of first examination, illustrating large temporal bone defect from epidermoid carcinoma.

Fig. 2, Case 4.—(Postoperative) X-ray showing operative defect following subtotal resection of temporal bone.

The patient consented to surgical procedure for diagnosis. Through a postauricular incision, tumor tissue was encountered at the level of the lateral extent of the petrosa. The radiologist agreed to the administration of deep x-ray therapy. This was not completed, for the patient stated that it caused her to feel so ill, that she voluntarily discontinued treatment. In January, 1953, four months after the initial examination, there developed partial left facial paralysis, and the pain in the left side of the head and neck became even more severe, if possible. The increased amount of bone destruction as seen by repeated roentgenograms was striking. The radiologist suggested that there might be some chance of attacking the tumor in soft tissue, if the involved bone could be removed.

She was prepared for this by ligating the left common carotid artery; and three days later, using local anesthesia, by ligating the internal carotid artery. A carotid bifurcation lymph node was removed, and microscopic examination failed to disclose tumor cells. One week after ligation of the internal carotid artery, through an enlarged postauricular incision, a subtotal petrosectomy was performed. Malignant tissue was found in the auricle, the temporomandibular joint, the soft tissue of the neck beneath the tympanum, the dura of the middle cranial fossa, and at the petrous tip. She refused further x-ray therapy. Her postoperative course consisted of sloughing of tissue around the operative site, pain necessitating large doses of opiates, and starvation. Her death occurred three months following the second operation, or 12 months following the onset of symptoms.

CASE 5.—Mr. J. H. L., aged 47 years, was admitted to the hospital December 16, 1953, because of inability to swallow. Secondarily, was the complaint of an extremely foul discharge from the left ear. Pain was not a major complaint. Relatives stated, without certainty, that the discharge from the ear had been present for many months, that he had become increasingly ill over the past few weeks, and that in the last month, he had become unable to swallow.

The examination revealed complete lack of function of the left cranial nerves V through XII. The patient's speech was hardly understandable, he was unable to swallow, and there was profuse, purulent, very foul discharge from the left external auditory canal. A fungating mass seemed to originate in the region of the tympanum. By roentgenography, the entire left temporal bone was destroyed,

with the exception of the very hard bone making up the labyrinth. When the relatives were informed of the diagnosis, and of the grave prognosis, they removed the patient from the hospital, without treatment, less than one week following admission, and death occurred eight days later.

CASE 6.—Mr. C. F. F., aged 44 years, a business executive who represented his United States company in the Philippine Islands, first noticed pain in the region of the right maxillary sinus in the summer of 1952. The second right upper molar tooth was extracted, with subsequent discharge from the socket, which did not heal. Nine months later, microscopic examination of tissue from the socket revealed the presence of epidermoid carcinoma. He immediately came to Boston, where partial resection of the right maxilla, and radical dissection of the right side of the neck were performed in May, 1953. Tumor cells were found in the glands from the neck. Before leaving the hospital, he noticed that his right ear felt "plugged up." He received treatment for the ear condition. He came to Atlanta to live with relatives, returning to Boston for observation as directed by his surgeon. During the summer of 1953, he received 4000 r of deep x-ray therapy to the right side of his head and neck.

On examination in June, 1953, six weeks following the surgical procedures, straw-colored fluid could be seen in the right middle ear, medial to an intact drum membrane. There was no evidence of a tumor mass in the ear. Neither was there evidence of tumor in the nasopharynx, nor in the neck below the tip of the mastoid process. Pain was not a predominant symptom, until five months after the operation; then it became severe, and was located in and around the right ear, radiating to the right side of the occiput. It was worse when the head was held in certain positions, and at night, when he turned from side to side in bed. Roentgenograms disclosed generalized clouding of the cells of the left mastoid, and decalcification of the petrosal floor. Ventricular air study was not diagnostically helpful. The only relief from the "stopped up" right ear, followed myringotomy and subsequent inflation. On November 2, 1953, six months after the operation, and four months after the deep x-ray therapy, the right middle ear was noted to be free of fluid, the drum membrane was inact, and the patient did not have the feeling of the ear being stopped up. Nevertheless, the pain in the right side of the head persisted. Examination revealed a smooth swelling in the region

of the posterior wall of the right maxillary sinus, and a firm mass between the angle of the jaw and the sternomastoid muscle, on the *left* side. He returned to Boston for further diagnosis and treatment, especially in reference to the mass in the left side of the neck. Following that, his course, which had never been favorable, became rapidly worse, and he died a month later.

At autopsy, there was found a tumor measuring five to seven centimeters in diameter, which had replaced practically the entire right petrosa as a "soft, friable, yellowish-white tumor." It had surrounded the petrous portion of the carotid artery, compressing its lumen to about one-fourth its normal size, and invading the artery to the media; however, tumor cells were not found in the media. The tumor had attacked the adjacent portions of the occipital bone, and had spread out generously into the sphenoid bone in the middle fossa. It had filled the sphenoid sinus, even into the left side of the sinus. There was extensive involvement of the dura mater over the right petrosa. There was no ulceration of the mucous membrane of the nares or the nasopharynx. Microscopic examination of all portions of the tumor revealed epidermoid carcinoma, consistent with the original tumor of the right maxillary sinus.

CASE 7.—Mr. G. B. L., aged 61 years, gave a long history of varied illnesses, starting with suppuration of the left ear in 1915. Over the years there was history of infection in the right ear, too. A malignancy of the urinary bladder was said to have been successfully treated in 1948. He first noticed pain in the left ear in May, 1952, was operated for radical mastoidectomy in August, 1952, and the operation was partially revised in April, 1953. Whether he was free of pain after the first operation is uncertain, but he was comfortable for seven days following the revision. The foul discharge had not been altered. Approximately two weeks after the second operation, he suddenly developed weakness of the left side of his face, the left arm, and left leg. This was thought to be due to a cerebral accident.

At the time of admission to an Atlanta hospital, in May, 1953, he was seen to be a small, emaciated man weighing 97 pounds. In addition to the weakness of the muscles on his left side, he had a very foul smelling discharge emanating from the left radical mastoid cavity, which was partially filled with unhealthy appearing granulations.

Biopsy and repeated biopsy from these granulations revealed epidermoid carcinoma. Roentgenograms did not show bone destruction other than in the operated area.

Operation consisted of upper one-third left neck dissection, and subtotal removal of the left temporal bone. This included the squama with the zygomatic process of the temporal bone, the temporomandibular joint together with the head and neck of the mandible, the mastoid process and external auditory canal, and the petrous bone to the medial limit of the internal auditory meatus. The bony plate on the superior aspect of the carotid artery was removed. Tumor cells were found in tissue from all parts of the operated area, the dura of the middle cranial fossa, and even the occipital artery.

He reacted quickly and satisfactorily from the surgical procedure, and the spinal fluid leak ceased in about five days. He was free of pain for two months during which time the operated area appeared healthy. He gained back the ten pounds lost after admission. Then came the return of the inevitable pain, the sloughing of tissue in the operative site, malaise, and left lateral rectus paralysis. Twenty-four hundred r of deep x-ray therapy was administered without beneficial effect. He died five months following the operation. A few hours prior to his death, there occurred a large brain herniation through the area of exposed dura.

At autopsy, in addition to the diffuse, purulent meningitis and herniation of temporal lobe brain, the sphenoid bone of the left middle cranial fossa was found to be grossly infiltrated with the tumor tissue, even in the area where the adjacent temporal bone had been removed. This seemed to indicate that the disease might have been there at the time of the operation five months previously. No tumor tissue was found anywhere other than in the contact area of original involvement. The picture was that the surgical procedures were too little, and far too late.

STATISTICS

The ages ranged from 33 to 61 with an average of 47, and the sex distribution was about even, there being 4 males and 3 females. Chronic suppuration of the ear, prior to the present illness, was present in two of the seven cases (28.57%). One patient developed metastases.

LITERATURE

A perusal of the literature brings out three fairly constant statements: that epidermoid carcinoma of the temporal bone is rare, that the results of treatment are uniformly poor, and that it tends to be superimposed upon a chronic discharging ear. Of the uniformly poor results of treatment, there seems to be no argument; of the other two statements, there is less certainty. From the amount of literature, on the subject, one would not get the impression that it is rare, and Schall[1] pointed out that "neoplasms of the ear are not medical curiosities." That epidermoid carcinoma of the ear is usually superimposed upon chronic infection of the ear is open to question. Furthermore, Risch and Lisa[2] stated that "foreign observers" have drawn a difference between the primary carcinoma of the external auditory canal which is secondary to a chronic running ear, and the type of carcinoma that arises in the absence of chronic otorrhea.

The splendid articles by Furstenberg,[3] Figi and Hempstead,[4] Grossman, Donnelly and Snitman,[5] Guttman,[6] Wahl and Gromet,[7] and Rosenwasser,[8] are only a few to be found in the literature. The Matticks[9] stated that they are in agreement with these men as to the management of these tumors, that radical mastoidectomy with radium implantation into the middle ear and mastoid, and additional high voltage x-ray therapy is important. House[10] stated that an early diagnosis is absolutely necessary, for by the time that the tumor becomes grossly visible, invasion of the underlying bone often has occurred already. Schall, a number of years ago, was emphatic in his belief that palliative surgery has no place in the treatment of this disease. He further stated, that as long as there is diseased bone present, there is no chance for help from radiation therapy, for a patient may receive sufficient irradiation to cause necrosis of bone and still not kill the tumor cells. Towson and Shofstall[11] opined that "treatment has been too conservative both on our part and that of others." Ward, Lock, and Lawrence[12] suggested radical neck dissection, combined with radical removal of the temporal bone. Although they were discussing carcinoma of the external auditory canal and middle ear, and, therefore, did not stress petrosectomy, it is my feeling that their type of operation is applicable to complete temporal bone removal, with the modification that more attention be placed on petrous resection, and the neck dissection confined to the upper one-third. Campbell, Volk and Burklund[13] attempted total removal of the temporal bone for adenocarcinoma. From their description, it is diffi-

cult to ascertain whether they were able to remove the entire petrosa; however, they stated that their patient's life was more livable for his remaining 16 months.

The idea of operation for resection of the petrous bone is not a new thought. Heyer,[14] in 1897, carried out such a procedure. A study of his article would lead one to believe that this, also, was a subtotal resection. He stated that he did the operation with rongeurs and that it was not difficult. He did not claim originality for this operation, but stated that he obtained his idea from Bircher,[15] who performed petrosectomy on a 25-year-old girl on September 20, 1892, for an abscess at the petrous tip. Bircher's patient survived.

DIAGNOSIS

Offhand, it would seem that the diagnosis of carcinoma of the temporal bone, which depends on the biopsy, would not be difficult. In instances where persons have discharging ears, observations may be made frequently enough that a change in the condition is noted and diagnostic measures, such as biopsy, instituted. Where the patient has never had ear trouble before, it is likely to be late, perhaps too late, when that patient first seeks medical advice. The patient C. F. F. (Case 6) illustrates the point that one can have carcinoma of the petrosa without presenting material for biopsy either in the middle ear or nasopharynx. This adds another diagnostic possibility in cases of fluid in the middle ear, and especially if it is unilateral. Pain, out of proportion to physical findings, is the most common symptom. X-ray evidence of definite bony breakdown in the temporal bone, if found in conjunction with carcinoma gives a bad prognosis.

COMMENT

In retrospect, it is questionable whether any patient of this series, except W. C. S. (Case 1), could have been helped by anything more, although the duration of known illness in the several patients ranged from only two to twelve months before medical consultation, and there was no delay in making the diagnosis, with one exception (Case 6). The patient described in Case 1 might have been saved by much more extensive removal of the temporal bone and the contents of the infratemporal fossa, at the time of the original operation, but this is now conjecture.

Regarding treatment for the disease, I would not be able to make an unqualified statement, since my observations are limited by the small number of patients, and the mortality rate is too noticeable. However, considering these observations together with those of others, it seems to me that there are three factors which mitigate the possibility of a "cure:" not seeing the patient in time to make an early diagnosis, the difficult decision of advising a patient who is in the early stages to undergo such a formidable procedure, and the almost technically impossible task of removing all of the diseased tissue. Even should an early diagnosis be made, especially in the patient who has not had chronic suppuration of the ear, the question arises of whether to carry out limited treatment to see if this will suffice, or to advise the radical operation with its resultant disfigurement, including facial palsy. If the limited treatment did not accomplish the desired result, the patient would move into the "too late" phase while being observed. Further, how many patients would agree to this mutilating operation? It would even tax the surgeon's nerve to advise it, in the early stages. When the disease has reached the place where both doctor and patient are satisfied that the radical operation should be done, there is probably little use in doing it.

Despite the undesirability, it is my opinion, as of this date, that the treatment for epidermoid carcinoma of the temporal bone resolves itself into the removal of the entire temporal bone, to be followed by radiation therapy. Removal of the temporal bone includes the facial nerve, and possibly the internal carotid artery. I do not agree with the statement that this is not difficult, even if the internal carotid artery is not removed. This latter poses a problem of its own. In one case, not reported in this series, the internal carotid artery was removed, and mortality resulted, although the common carotid artery had previously been ligated by progressive compression, over a period of eight days. Small comfort it is that metastases are infrequent. The original lesion seems not to need helpers in its destructive course.

SUMMARY

1. The case reports of seven patients afflicted with epidermoid carcinoma of the temporal bone, and the poor results of treatment, have been presented.

2. The lethal character and the rapidity of diffusion of this tumor in its local area are impressive.

3. Radiation therapy alone is not helpful.

4. No outline of treatment is recommended, for obvious reasons; but, recommended for consideration is the possibility of temporal bone resection followed by radiation therapy.

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LX

ELECTRICAL RESPONSES FROM THE AUDITORY NERVOUS SYSTEM

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For many years students of hearing have focused their attention upon responses to pure tones. This predilection for pure tone stimuli can be attributed to several, probably related, factors.

Early in the nineteenth century Fourier gave the world a mathematical technique for the analysis of complex sounds. In the middle of the nineteenth century, Helmholtz's monumental work oriented for decades to come the thinking of students of hearing in the concepts of localized resonance. As recently as a quarter of a century ago the sound sources of the laboratory were tuning forks and sine-wave oscillators. Such equipment limitations determined the stimuli that the experimenters could conveniently control.

The interest in pure tones carried with it a certain disregard for the factor of time. There were attempts to establish the validity of an I x t law in hearing. Such a law would establish a certain reciprocal relation between intensity (or power) and time, and thereby state that response is a function of the total energy of the stimulus only and is not determined by any particular integrating time of the auditory system. There were also experiments designed to determine the number of cycles necessary to establish a sensation of tone or to study the growth of loudness as a function of stimulus duration. However, the great majority of monaural experiments were carried out in a theoretical context in which time did not occupy a particularly important place. The dogma according to which "the ear is not sensitive to phase" contributed perhaps as much to making time a minor experimental variable as the inability of the experimenters to control precisely small intervals of time.

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Even the comprehensive program of psycho-acoustic experimentation, carried out by the Bell Telephone Laboratories under the direction of Fletcher, was still dominated by pure-tone theories, though the problem of noise interference received some attention. With the hindsight that we have today, we might be inclined to find this strange, since the Telephone Company's business was then as today a time dependent commodity par excellence: the transmission of speech or, more broadly, the transmission of information.

About a quarter of a century ago it became possible to record electrical responses to acoustic stimuli from animals. There was a period of hesitation: Davis and his group[1] introduced acoustic pulses or clicks (clicks had previously plagued experimenters as artifacts) among their stimuli in order to use the resolving power of the oscilloscope face with respect to time. They hoped by this means to separate out microphonic and neural components in the Wever-Bray phenomenon. However, the acoustic transducers and the calibrating equipment available for common laboratory use were still too rudimentary to guarantee the reproducibility of non-sinusoidal stimuli. Electronics and communications engineers had not yet become expert in transient analysis and pulse code modulation. Pulse circuits, electronic switches, thermal noise generators, pulse generators, and precise electronic timing devices became commonplace only in the wake of radar and sonar developments of World War II. While some electrophysiologists made use of acoustic and even electric pulses in order to trace the pathways of the auditory nervous system, others pursued the problem of the representation of frequency at various levels of that system. On the whole the latter group was motivated by the hope of finding anatomical or physiological correlates of psychophysical functions such as pitch perception.

Most of the psychophysical functions extant refer to pure tone stimuli. Electrophysiologists discovered rather quickly that the electrical responses that the unaided human visual system can discern show less and less relation to pure tone stimuli as one ascends the afferent auditory system of anesthetized animals. The higher levels of that system are clearly unable to follow in frequency those pure tones that evoke behavioral responses from the total organism.

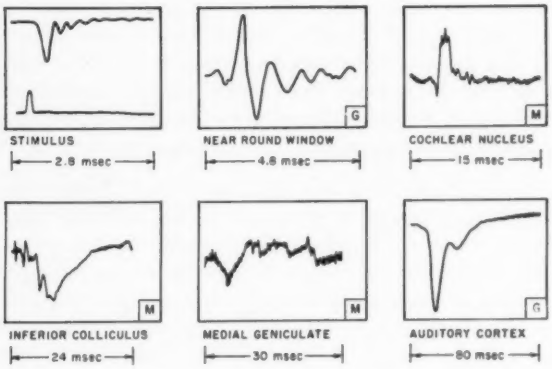
The onsets of tones—especially when these onsets are relatively sudden or even "clicky"—evoke clearly detectable responses at the auditory cortex, particularly when the Tunturi-Hind strychninization

technique is used. It appears at present, however, that a more thorough analysis of the activity that accompanies a quasi-stationary state (i.e., a pure tone after it has been turned on) will have to wait for help from modern electronic computers. With their aid we should be able to separate out the "stimulus-bound modulation" from the self-sustaining spontaneous activity that characterizes these higher levels of the nervous system.

In view of these difficulties Galambos and Davis[2] tried to get at the fine structure of neural activity in the auditory system with the help of microelectrodes. Instead of recording average activity at locations that are anatomically and electrically not too well defined, they attempted to record the activity of single neurones. Their significant findings involving such important concepts as the response area have advanced our knowledge considerably. These experiments (and more recent ones[3, 4, 5]) raised, however, new questions in our statistics-conscious age.

What are the sampling characteristics of experiments with microelectrodes? Is the total activity of a nucleus in the nervous system simply the sum of the activities of the individual neural units? In other words, how do you synthesize the response of the whole from a knowledge of responses of a few small parts? Are the action potential spikes the only significant events or must we pay more attention to such events as electrotonus and after-potentials?

These lengthy introductory remarks are intended to clarify the background against which our experiments were undertaken. In most of our experiments the stimuli have been brief clicks, i.e., impulsive stimuli that have frequency components throughout the response range of our acoustic transducer. (The author has long held the opinion that conventional pure tone audiometry could be supplemented advantageously by measurements in which clicks and other acoustically complex sounds would be used as stimuli. Such tests would get at certain temporal and dynamic characteristics of the speech reception process without running into complications of a verbal or even semantic nature.) But clicks do not have only the advantage of being "point" stimuli in time. They are also natural sensory stimuli that bear a certain resemblance to the signals of the nervous system. Electrical responses to clicks can be recorded and visually monitored at all levels of the afferent auditory system, and amplitude and latency characteristics of these responses can be meas-



CLICK RESPONSES FROM VARIOUS LOCATIONS OF THE CAT'S AUDITORY NERVOUS SYSTEM

Fig. 1.—Typical responses to clicks (well above threshold) at various locations of the auditory nervous system. The two traces in the box in the upper left-hand corner depict the electrical pulse across the earphone (lower trace) and the acoustic click into a 1-cc cavity. The responses in the boxes labeled G were recorded with fine wire (so-called "gross") electrodes; those in boxes labeled M were recorded with micro-electrodes (saline-filled micropipettes). The biggest deflections are of the order of several hundred microvolts. As is customary in most electrophysiological experiments, upward deflections indicate that the active electrode is negative with respect to the so-called indifferent or reference electrode. Note the increased time scale as we ascend from the periphery to the auditory cortex. (For further details on the stimulus-generating and recording equipment, see ref. 13.)

ured. Finally, it may be worth while to point out that the electrical responses to clicks are—at least at peripheral locations—in many respects remarkably similar in such animals as cats, monkeys, guinea pigs, hamsters, bats, desert rats and even pigeons.

PROBABILITY OF RESPONSE: A BASIC DATUM

The Zeitgeist (whom some of my friends are inclined to identify with Norbert Wiener) and the author are both biased in the direction of a statistical model for the behavior of the nervous system. We are inclined to interpret the electrical responses that our wire electrodes record as summated activity from a sample of a population of neural elements at a given station of the auditory nervous

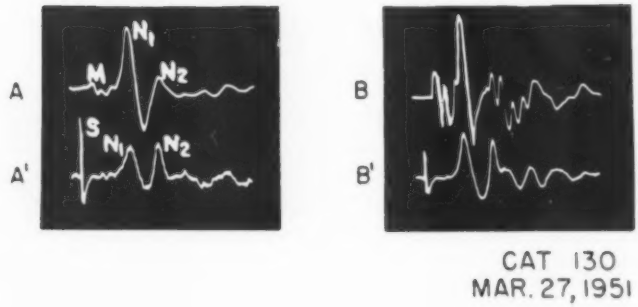


Fig. 2.—Click responses at round window of the cochlea (upper traces) and at a microphonic-free location on the cat's bulla; simultaneous recordings. S is the stimulus artifact that coincides in time with the electrical pulse across the phone. M is the earliest microphonic potential in the click response; N_1 and N_2 are the most prominent neural components representing summated action potentials. The traces on the left were recorded for a click 50 db below 0.6 volt across an PDR-10 earphone, while the traces on the right were recorded for a click 5 db above 0.6 volts. Note in B' the absence of the relatively high frequency microphonic potentials that stand out in B.[25]

system. The number of neural elements that contribute to a response depend upon the intensity of the stimulus that is used. As has been shown,[6] the amplitude of an evoked response can—within certain limits—be interpreted as an estimate of the probability of response of the neural population under investigation.

What do we mean when we talk about the probability of response of a neural unit or of a population of neural units? How is this concept related to the concept of threshold? Were we to assume that a given neural unit has a fixed threshold, we could completely predict its behavior once we knew the intensity of the stimulus (S) and the value of the threshold (T). If $S > T$, the unit would presumably always fire and if $S < T$, the unit would never fire in response to the application of the stimulus. Is the concept of such a fixed threshold realistic?

Most of the microelectrode records with which we are familiar show that neurones respond differentially to stimuli of different in-

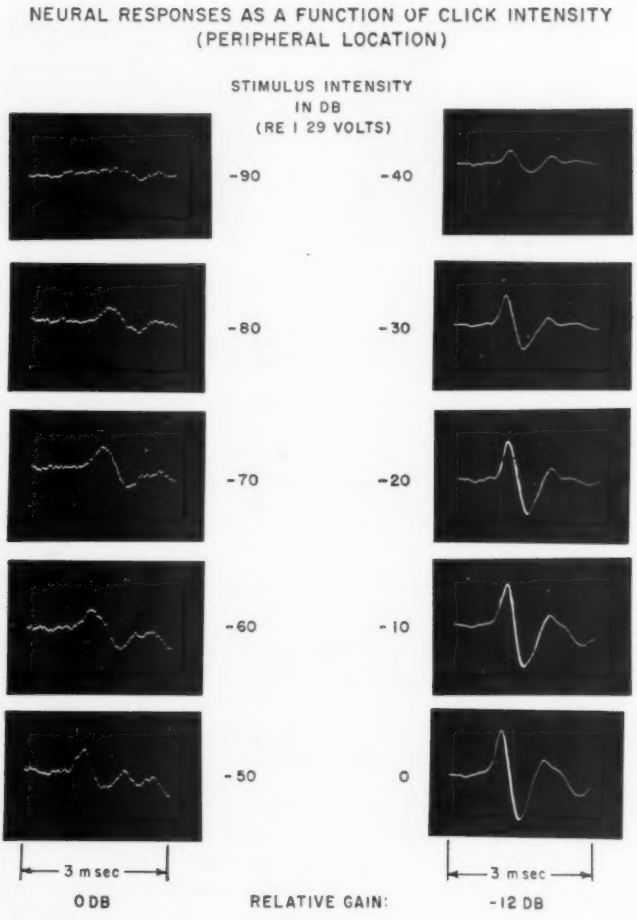


Fig. 3.—Typical click responses at a "microphonic-free" location covering a 90-db intensity-range (re 1.3 volt across the phone). Note that the voltage-gain of recording equipment in the right column is ¼ (-12 db) of the gain in left column. The growth of the "neurals" (N_1- and N_2-components) with intensity is clearly demonstrated; also the decrease in latency. The peak of N_1 represents presumably the time at which the greatest number of neural elements fire. Human thresholds for normal listeners lie around -95 db.

tensities. Galambos and Davis[2] have shown that single units respond at a higher rate to strong pure tones than to weaker ones. Let us now consider in some detail the response behavior of a single unit as we vary the intensity of our click stimuli. We simplify the situation by assuming that the unit is not spontaneously active. A click that is too weak will evoke no response no matter how often the stimulus is presented. As the intensity of the stimulus increases, the unit will respond to, let us say, 15 per cent of all click stimuli presented at a particular intensity level. If we increase the stimulus intensity further, the unit will respond more frequently: for instance, 50 per cent of the time. Finally, for a click stimulus that is strong enough, the unit will respond 100 per cent of the time. In other words, every click stimulus will evoke at lease one so-called "spike response."[7] As the relative frequency of responses of the single unit increases, the latency of response decreases. The above statements are by no means universally true, but they seem to hold for the majority of single units that have been sampled in microelectrode experiments.

This evidence from neural elements in the intact animal favors the view that the threshold of any single neurone fluctuates over a certain range. This range may vary for different neural way stations and may also vary for different units belonging to the same nucleus. There is also ample evidence for the statement that units can be classified on the basis of their average threshold. When we talk about the probability of response of a neural population we think of an experiment in which a click stimulus would be presented a great number of times. If we were able to record from each element of the population we could count the number of units that fired at each stimulation presentation. We would thus establish that, for example, on the average one-tenth of all units fire in response to a stimulus of intensity S_1. The units to fire would not be the same for each stimulation presentation. For a stimulus of intensity $S_2 > S_1$ on the average a greater fraction out of the total number of units would be found to fire, but we might find that for a particular presentation of S_2 some units would not fire that had previously fired in response to a particular presentation of S_1.

Probability of response thus becomes our basic datum to be manipulated by varying the conditions of stimulation. Exposure to intense sounds, masking by various amounts of noise, serial presentation of several stimuli—all these conditions modify the ampli-

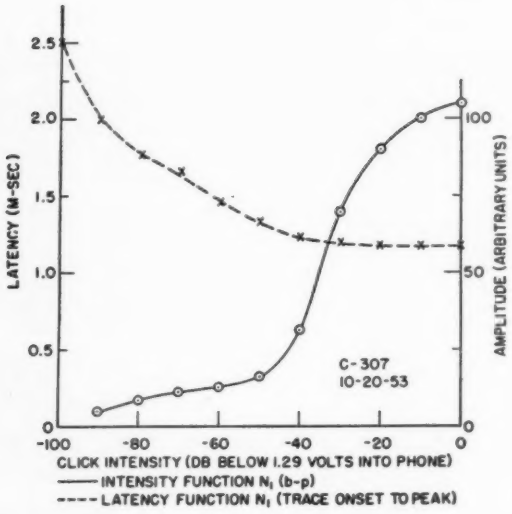


Fig. 4.—Amplitude and latency of N1 as a function of intensity. The data plotted are average values computed from the experiment illustrated in Fig. 3. The amplitude of N1 is measured between the base line and the peak. Note that the function grows in two distinct stages. The first stage, characterized by slow growth and a slight plateau, covers the first 40 db or so above "threshold." This same behavior has been seen in other animals and has led to the development of a mathematical model made up of two neural populations; one of these populations consists of a small number of sensitive elements; the other of a larger number of less sensitive elements. The latency data plotted here represent intervals between the start of the trace (time at which the electrical pulse of 0.1 msec. duration is delivered to the earphone) and the peak of N1. This interval includes an acoustic delay of about ¼ msec. The shortest time-interval between the M-component of the click-response (see Fig. 2) and the "start" of N1 is of the order of ½ msec. Note, however, that the sharp break in the trace that one might label onset of N1 is at most higher intensities preceded by a gradual rise.

tude of the evoked response or operate (as we might say) upon the response probability of the population.

A SUMMARY VIEW OF THE AFFERENT PATHWAY

We have recorded electrical activity at various locations of the afferent auditory pathway between the periphery (commonly a location on or near the round window of the cochlea) and the auditory cortex. Most of our data come, however, from these two extreme locations both for reasons of accessibility and because they represent the extreme stations of the ascending auditory pathway. The peripheral location permits us a view of the earliest neural signals into which the stimulus has been coded. The cortical location presents a picture of the response evoked by activity along the most direct afferent route.

Our experiments were done on anesthetized animals and, unfortunately, a measure or a scale of anesthesia is not yet available to make the preceding statement truly meaningful in a physiological sense. We can make only a crude estimate of the contaminating effect of a certain dose of a given anesthetic. Békésy's warning[8] that "for every level of anesthesia we will probably have a hearing theory" should remain ever present in our speculations.

Before we proceed to a more thorough examination of the responses at both the peripheral and the cortical locations, let us take a quick, almost schematic view of some of the characteristics of responses to clicks at strategic locations along the auditory pathway. Figure 1 illustrates the fact that as we ascend the auditory pathway, both the latency and the duration of our responses increase. In order to get a somewhat more quantitative view of the locations from which the responses have been recorded, let us look at certain recent data by Chow,[9] who estimated the total number of neurons and the number of cells per unit volume from cell counts on the central auditory system of two monkeys (see Table 1).

It is not the author's intention to convey the impression that at these locations all the units respond to auditory stimuli and, in particular, to clicks. No such proof has been given up to the present, and there is, on the contrary, some evidence from microelectrode experiments that many units "contacted" fail to respond.

TABLE 1.

	TOTAL NUMBER OF CELLS	CELLS IN 0.002MM^3	LATENCY OF ONSET OF ELECTRICAL RESPONSE (CLICK OF MEDIUM INTENSITY)
Cochlear Nucleus	About: 90,000	About: 30	About: 2 Milliseconds
Superior Olivary Complex	35,000	30	
Lateral Lemniscus	40,000		
Inferior Colliculus	400,000	85	4 Milliseconds
Medial Geniculate (Parvocellular)	360,000	65	6 Milliseconds
Medial Geniculate (Magnocellular)	60,000	40	
Auditory Cortex*	10,000,000	185	8 Milliseconds

*On the basis of these figures and of the generally accepted figure of 30,000 fibers for the auditory nerve, Chow finds that the auditory nervous system "expands" in a ratio of about 330:1. However, more recent maps of the extent of monkey cortex activated by clicks[10] would lead to a considerably larger estimate for the total number of cells in the auditory cortex.

THE INTENSITY FUNCTION FOR CLICKS

If our wire (or gross) electrodes actually record summated activity from many neural entities, we can expect to find that as the stimulus intensity increases there will be a decrease in the amplitude of the N_1-response and also a decrease in its latency. A greater fraction of the total population should respond to a stronger stimulus and should do so on the average at an earlier time after delivery of the stimulus. Let us test these hypotheses by examining what happens at or near the round window of the cochlea.

As the click intensity is increased to levels that are 60 db above human threshold, neural components of the round window response to clicks get contaminated and overwhelmed by the microphonic components of this same response. We have, however, shown[11] that there are locations (both on the cat's bulla and inside it) at which

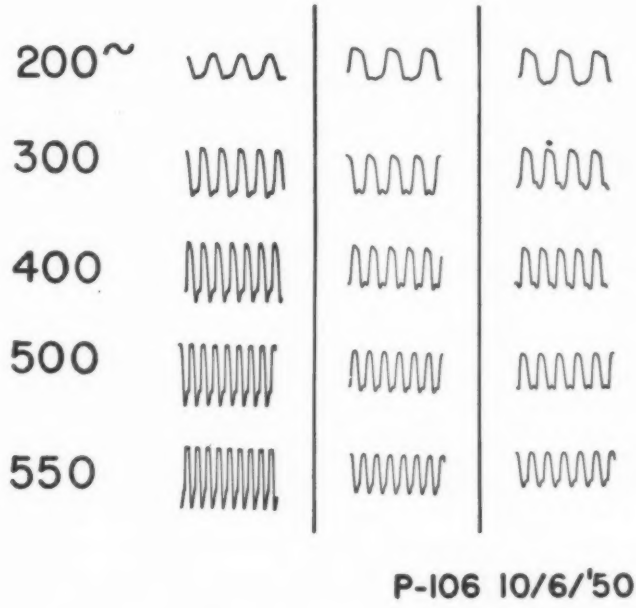


Fig. 5.—Neural responses to intense pure tones.[26] The large, more or less sinusoidal responses are microphonic potentials recorded in response to pure tones between 200 and 550 cps. The "neurals" are the small notches whose position in the cycle remains invariant for a given frequency and intensity. As the intensity is increased, the neurals are seen to move to an "earlier" position in the cycle. The three columns have not been recorded at equal gains; the acoustic stimuli for all three columns were rather intense; in the left column the voltage across the phone was 0.3 volt, in the middle column 1.0 volts, and in the right column 2.0 volts.

click responses that are relatively free from microphonics can be recorded. Such recordings permit us to examine the way in which the amplitude of the so-called first neural (N_1) varies as a function of click intensity. Figure 2 illustrates the advantages of these so-called "microphonic-free" locations, and Figure 3 shows what happens as the click intensity is varied over a range of 90 decibels. Figure 4 summarizes the behavior of the amplitude of the first neural and of the latency of the peak of the neural. The data of this graph are clearly compatible with the previously stated hypotheses.

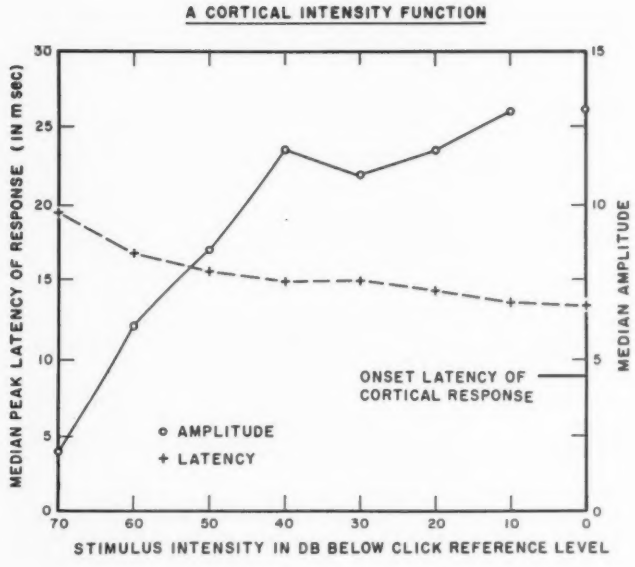


Fig. 6.—Click responses recorded at the auditory cortex: amplitude and peak latency of surface-positive deflections. The growth of this amplitude function occurs for the first 40 db above "threshold" (defined as that stimulus intensity at which the experimenter can visually detect the presence of an evoked electrical response 50 per cent of the time). Note the contrast with the amplitude function for N_1 (Fig. 4). (The contrast can be further enhanced and the initial slope of the cortical intensity function can be made steeper if strychnine is applied at the surface of the cortex). The amplitude is here plotted in arbitrary units. Only median values out of fifteen responses are given, and the reader should be cognizant of the fact that for a given stimulus intensity the amplitude varies considerably in size, much more so than does the corresponding amplitude of N_1.[27] The latency of the peak of the surface positive response and the latecy of the onset of electrical phenomena that are commonly associated with cortical activity both show a gradual decline as the stimulus intensity increases. Both these measures are somewhat sensitive to anesthesia.

At the present time it would seem unwise to commit oneself to postulate that a single population of neural units is responsible for the general appearance of the N_1 curve. As a matter of fact, there is a good deal of evidence for two sets of units: a smaller, more sensitive population and a second population less sensitive (i.e., having higher thresholds) but larger in number. Data on the variability of the amplitude as a function of stimulus intensity bear out the statistical prediction according to which the ratio of mean amplitude to variance decreases as the fraction of the population that fires increases. This is our present picture of the way in which the amplitude of N_1 varies as a function of stimulus intensity.

NEURAL RESPONSES TO PURE TONES

Much of what we have said about the N_1-response to clicks holds in principle also for neural responses to pure tones of low frequency. Figure 5 illustrates several points: a pure tone gets "recoded" into a series of neural "pips" that occur at the same point in each cycle of microphonic. The size of these neural pips (again representing summated activity) increases with stimulus intensity. Furthermore the latency of these pips decreases with stimulus intensity; i.e., the pips move to an earlier spot in the cycle. Records such as these lead us to believe that we might be able to gain an understanding of the behavior of neural responses to pure tones if we could successfully predict the behavior of series of neural pulses. Of necessity we will have to deal with such phenomena as adaptation or equilibrium when we are concerned with records of neural responses to prolonged pure tone stimuli.

RESPONSES AT THE AUDITORY CORTEX

Let us now consider the responses to clicks that are recorded at the auditory cortex. Various authors, and in particular Hawkins,[12] have shown that the shape of these responses varies here over a considerably wider range than at the periphery of the auditory nervous system. The shape depends critically upon the location of the electrode, the state of anesthesia of the animal, and the intensity level of the click stimulus. This circumstance makes it much more difficult to interpret our amplitude measure of the response as a representation of the probability of response of a population of auditory neurones. It still remains possible, however, to use relative measures of amplitude in a meaningful way.[13]

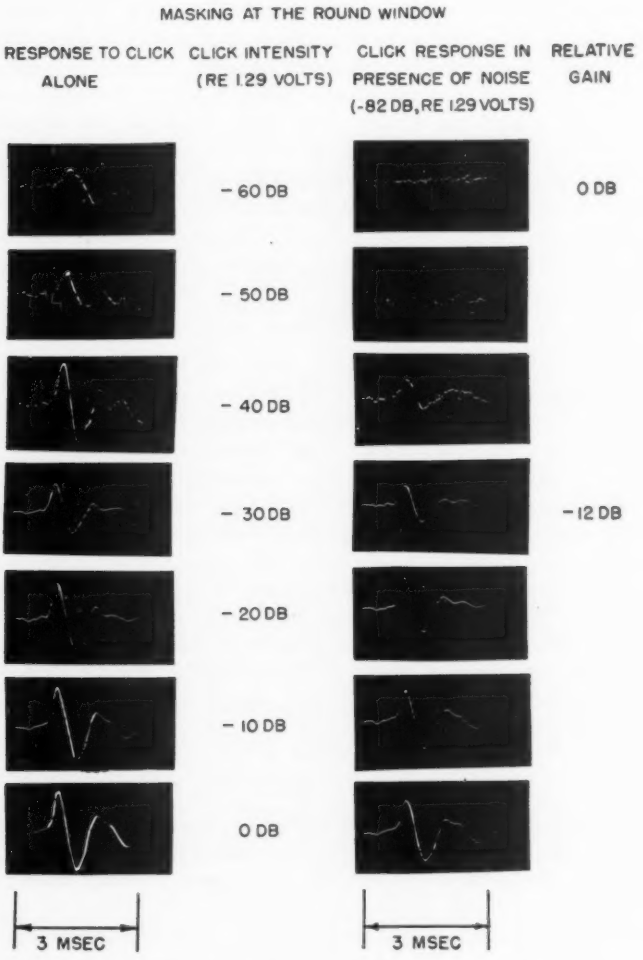


Fig. 7.—Click responses in the presence of wide-band noise.[28] The left column shows typical responses to clicks ranging in intensity from -60 db to 0 db re 1.3 volts. The right column shows how these responses are modified when a broad-band "masking" (or background) noise is presented simultaneously with click stimuli. The intensity of the noise remains the same for all click intensities. Note that the neural responses to the weakest clicks are wiped out; neurals in responses to stronger clicks are reduced in amplitude.—The gain of the recording equipment is constant for the three top traces in each column; the gain for the four bottom traces has been reduced by 12 db.

If we restrict ourselves, however, to the so-called classical picture of the surface-positive cortical response (Fig. 1) and if we measure the amplitude of that response, we find that the intensity function behaves as shown in Figure 6. There is a much more abrupt rise for weak stimulus intensities, and then there is a very pronounced flattening. Increase in stimulus intensity is again accompanied by a decrease in the latency of both the peak and the onset of the response. These cortical amplitude functions of Figure 6 are by no means universal; there are locations on the auditory cortex at which there is a two-stage growth in this function. However, functions like the one shown in Figure 6 are recorded at a large number of locations.

We have recently obtained data on the variability of the amplitude of cortical responses. It will come as a surprise to no one that cortical responses to clicks are singularly more variable in amplitude than those recorded at the periphery. The extent to which such variation takes place might be assumed to be related to the amount of spontaneous activity present, i.e., among other things to the level of anesthesia of the preparation.

MANIPULATING THE BEHAVIOR OF N_1

Now that we have outlined our views on the electrical activity of the auditory nervous system, views in which probability of response is the key concept, let us give a few sample illustrations of experiments in which we can successfully manipulate this statistical variable. The phenomena that we shall consider have all one property in common: the microphonic components of the round window response to clicks remain essentially unchanged, while there are profound changes in the behavior of the amplitude of the so-called first neural. These changes thus reflect events that occur beyond the microphonic. Since N_1 represents the neural input to the auditory nervous system we should expect it to have some influence in shaping the behavior of the whole organism in response to sound.

These experiments are the counterparts of well-known psychoacoustic or physiological experiments; the effect of various stimulus conditions upon the N_1-component of the click response was systematically investigated. In some experiments clicks were presented against a background of wide-band noise, a typical "masking" situation (Fig. 7); in others the after-effects of exposure to strong sounds upon the click response were studied[14] (Fig. 8); in still other

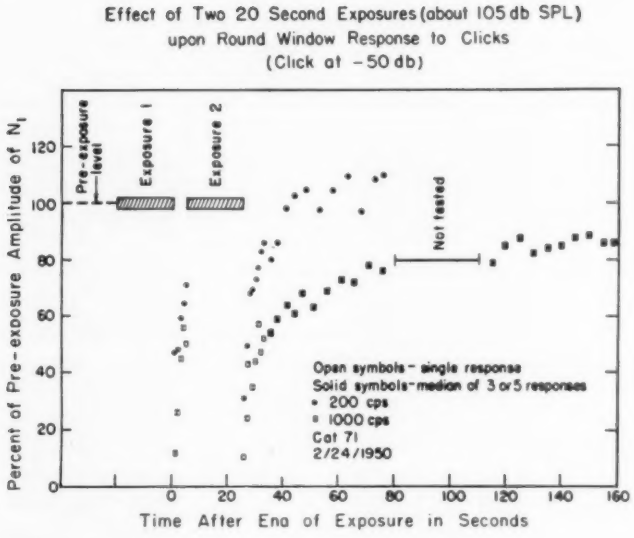

Effect of Two 20 Second Exposures (about 105 db SPL)
upon Round Window Response to Clicks
(Click at −50 db)
Percent of Pre-exposure Amplitude of N1
Pre-exposure level
Exposure 1
Exposure 2
Not tested
Open symbols = single response
Solid symbols = median of 3 or 5 responses
200 cps
1000 cps
Cat 71
2/24/1950
Time After End of Exposure in Seconds

Fig. 8.—Recovery of the N_1- component of the click response after exposure to pure tones at 105 db sound pressure level.[14] Different exposure stimuli affect the response to click stimuli differentially.[7] After exposure to a 200 cps tone, N_1 reaches and exceeds its pre-exposure amplitude fairly rapidly. (This supernormality after exposure to low-frequency tones has recently been investigated by Hughes.[15]) After exposure to a 1000 cps tone, the recovery process is stretched out in time; no supernormality is observed. If the testing for recovery is suspended for ½ minute the course of the recovery-curve is not altered. The test clicks are presented both before and after exposure at the rate of 1/second.

studies[6, 13, 15] (Fig. 9) responses to pairs of clicks were investigated in a manner that resembles the classical conditioning paradigm of physiologists.

This is not the place to report our findings in detail. Suffice it to say that the data point to N_1 as a rather sensitive indicator of the dynamic equilibrium of the sense-organ. This statement derives its significance from the spreading use of the Békésy audiometer; measurements with this instrument put increased emphasis on short time characteristics of the auditory system in contrast to the more static features of customary audiometry. The experimental conditions af-

fect N_1; i.e., the fraction of the total population that fires. These results can in principle be checked against the predicted behavior of N_1 on the basis of a statistical model. In this probabilistic framework the conclusions from the experiments exemplified in Figures 7 and 9 strengthen our initial assumption according to which the electrical activity of the auditory nervous system can be described in statistical terms in a manner that is both useful and perhaps even economical. This assertion does not imply that we understand as yet the probability mechanisms that underlie response fluctuations.

ELECTROPHYSIOLOGY, INTEGRATED BEHAVIOR AND PSYCHOPHYSICS

We know today that the behavior of populations of neural elements is smoother, i.e., less variable, than the behavior of any member of that population. This is presumably what von Neumann has in mind when he talks about "reliable organizations out of unreliable elements." The behavior of the whole organism results from, or at least occurs after, activity of a long chain of neural way stations in series. Integrated behavior may even be based on the combined effects of several parallel pathways. There is, however, at present no reason for assuming that the final output of the organism will stand in a strict one-to-one relation to the acoustic stimulus.

Under carefully controlled laboratory conditions anesthetized animals will yield electrophysiological responses that exhibit fluctuations when the identical stimulus is presented over and over again. Response is thus in the statistician's jargon a variable in distribution. Even the simplest psychoacoustic judgments are afflicted with the variability of the underlying neural processes. The wise researcher will not only take account of this fact but may even use it to advantage in the design of his experiments. The variability of certain electrical events in the auditory system is only one of the factors contributing to this over-all lack of stereotypy in human or animal behavior. Our training predisposes most of us to exhibit a preference for strictly causalistic systems, i.e., systems that behave along lines of Newtonian mechanics. A sensory system that functioned according to such rules would not only lack flexibility but might also present the organism with a maintenance bill that it could ill afford to pay. The extent of the zone of statistical fluctuation may yet turn out to constitute an important experimental and even clinical datum.

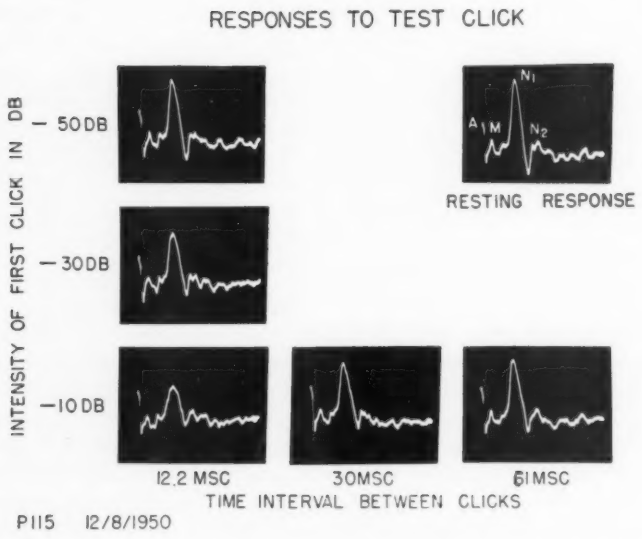


Fig. 9.—Round window responses to the second of a pair of clicks.[6] If the second click or test click is presented (at -45 re 0.6 volt) alone, we obtain the resting response. If it is preceded at an interval of 12.2 milliseconds by conditioning clicks of increasing intensity, we obtain the responses shown in the left column. If the intensity of the first or conditioning click remains set at -10 db (re 0.6 volt) and if the time interval between clicks is lengthened to 30 and then to 61 milliseconds, we obtain the responses in the horizontal row. Note that the microphonic component (M) remains unaffected while the neurals are reduced in amplitude in varying degrees. The time characteristics of this phenomenon preclude a simple explanation in terms of the refractory period of the auditory nerve. (A is stimulus artifact.)

These remarks bring us to a set of questions that we have carefully avoided up to the present point. What is the relation between the kind of electrophysiological responses that we have dealt with and acts of integrated behavior or psychophysical judgments that the total organism emits when faced with similar stimulus situations?

Let us first of all look at the temporal relations that are involved. We have seen that a click evokes activity at the auditory cortex approximately ten milliseconds after the sound reaches the ear drum.

We have seen that it is difficult to say how long this activity lasts and in particular over how long a period after this activity effects can be detected.

Data on the latency of middle ear muscles are somewhat contradictory but ten milliseconds probably represents a reasonable figure for the lower bound. Galambos et al.[16] have recently found that the latency of the eye blink to a strong click is of the order of 35 or 40 milliseconds. Finally, the fastest human reaction times to a simple auditory stimulus exceed 100 milliseconds. Complex discriminations of auditory stimuli often entail even in the case of trained observers as much as a second's delay. Let us also note that reaction times to weak stimuli are much longer than to strong ones and that the differences exceed by many milliseconds the differential delays on the afferent side.

It has previously been stated that it was a far cry from the cochlea to the cortex; we can now add that it is a long time between the onset, or even the peak, of electrical activity at the auditory cortex and those, often verbal, responses of the whole organism that we commonly associate with the word "hearing." In other words judgment processes take time, and there is more to hearing than just afferent and efferent events and delay times.

Under these circumstances you will understand my hesitancy to mention the word "loudness" when I discussed intensity functions at the periphery and at the cortex. I do not share the optimism of a famous physicist who recently expressed his surprise that nobody had yet put an electrode on the auditory nerve in order to find out what the *true* loudness function was really like. Nor is the widely held assumption that loudness is simply proportional to the total number of nerve impulses necessarily any closer to the intricacies of the current loudness controversy.[17]

Obviously the electrical activity of the auditory nervous system is not unrelated or irrelevant to the total process of hearing. It would, however, appear unwise to view auditory discrimination processes as "nothing else but" the counterpart of the electrophysiology of this particular sensory system. There are indications for some kind of gross parallelism in the realm of absolute sensitivity provided you pick the right definitions for both behavioral and electrophysiological thresholds.[18, 19]

It would seem wise in particular to refrain from delegating too much responsibility for perceptual judgments to any one of the neural way stations. There must exist a functioning cochlea as an input to the auditory nervous system, but the recently observed tendency to put pitch discrimination into the auditory cortex, as noted in the writings of Tunturi, is to be viewed with skepticism. This is a rather surprising switch after decades during which the cochlea was held responsible for the "fineness of tuning." Within the last decade numerous experiments have been carried out in which the discriminatory abilities of animals were studied after ablation of the auditory cortex.[20-24] The generality of the findings shows these animals to be still as capable of being trained to make simple frequency and intensity discriminations with about the same acuity as unoperated control animals. Unfortunately data on the reaction times of the operated animals are not available. This aspect of their behavior might have shown a deficit as was the case for more complex auditory discriminations.

The conclusions to be drawn from studies of the electrical activity of the auditory nervous system have thus both their interest and their limitations. These investigations are no panacea for those who would like to understand the normal and pathological reactions of man in response to acoustic stimuli. They offer an obvious fascination to those who are students of the central nervous system per se. They have dramatically focused the attention of those who are interested in complex auditory discrimination processes—such as speech communication—upon the role of temporal processes. They have forced upon us a statistical view of the behavior of the auditory system.

These studies present in some sense severe limitations upon the speculations of auditory theorists.* On the other hand the interaction of electrophysiological, behavioral and psychophysical studies should help us to a better understanding of what we mean by hearing.

This paper is based on data collected during the last six years both at the Psycho-Acoustic Laboratory at Harvard University and by the Communications Biophysics group of the Research Laboratory of Electronics at the Massachusetts Institute of Technology. The author owes a debt of gratitude to his colleagues and students who have been responsible either solely or jointly for the recordings

*The term auditory theory should here not be interpreted as referring to a theory of pitch perception only.

and the analysis of these data. He is particularly indebted to Robert M. Brown, Lawrence S. Frishkopf, Robert Galambos, Katherine S. Harris, George Heise, John R. Hughes, Josiah Macy, Jr., William J. McGill, Karl Pribram, David H. Raab, Burt S. Rosner, and Mark R. Rosenzweig. The author bears, however, sole responsibility for the conclusions he has drawn in this paper.

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Clinical Notes

LXII

A NEW INSTRUMENT FOR USE IN SHORTENING THE NASAL SEPTUM

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In a complete rhinoplasty, performed with the intent of improving the contour of the external nose, there are a number of pitfalls which may impair the final success of the operation.

The primary incision is made at the muco-cutaneous junction of the vestibule with a Bard-Parker No. 11 knife and the skin is undermined to admit the saw for removing the hump over the nasal bridge. After the nose has been narrowed by cutting through the anterior processes of the maxilla, and these have been pressed medially, there always remains the shortening of the nasal tip to secure the desired esthetic effect.

To cut through the nasal cartilage freehand with a knife or scissors is not easy. The elasticity of the cartilage makes accurate incision in a straight line difficult, and the result may be a curve or an irregular, ragged cut, which requires trimming. This may result in the removal of too much or too little tissue.

To overcome this difficulty, the writer presents a cartilage, clamp, with which the cartilage can be held firmly, guiding the knife exactly as desired.

This instrument resembles a slender stainless steel hemostat seven inches in length. The blades are 2 3/16 inches in length and one quarter inch in width. They are lightly cross-hatched at one-quarter

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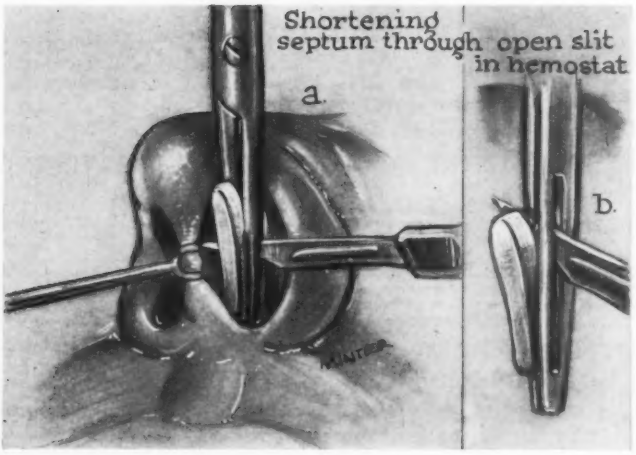

Fig. 1.—(a) The hemostat is in position; (b) The knife has cut through the cartilage, which is ready to remove.

inch intervals, and are fenestrated for a distance of 1 13/16 inch. The slits are about 1/32 inch in width.

When the nasal cartilage is to be shortened, its lower end is drawn outside the incision, with the clamp at the line of incision, the fenestra marking the exact line. With a Bard-Parker No. 11 blade inserted into the slit of the clamp, the incision can be made cleanly and accurately.

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LXIII

CYST OF THE NASAL VESTIBULE

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While the textbooks on diseases and histo-pathology of the ear, nose and throat give a more or less extensive anatomical or histological description of the nasal vestibule, most of them do not mention any pathological process in this region. In the literature no paper on cysts of the nasal vestibule could be found except by Ajkay[1] and one by Terracol and Gesp[2] who mention other authors without stating references. Accordingly it appears that pathological processes in the nasal vestibule are rather infrequent. Though benign they may cause disfigurement.

A 43 year old white female first seen on February 5, 1953 had had, for three years prior to examination, a swelling on the left side of her nose with distortion of the left ala. Supposedly this swelling was not increasing in size and did not cause any pain or difficulty in nasal breathing. She was concerned over the distortion.

Examination showed the left ala elevated and the frontal process of the maxilla bulging outward; it felt solid. The mucosa on the floor of the nose in the anterior part was bulging inward. The inferior turbinate had a dusty purplish appearance posteriorly and laterally. The sinuses transilluminated well. X-ray films of the sinuses showed a round density in the floor of the left naris having the appearance of a cyst, and seemingly attached to the lateral nasal wall. The sinuses did not show any pathological changes. Biopsies were made from the posterior and anterior lateral portions of the left inferior turbinate, but did not show any malignancy. About 2 cc of yellowish fluid was aspirated from the mass on the floor of the nose.

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The opinions expressed in this paper are those of the author and are not to be construed to reflect the views of the Office of the Surgeon General, Department of the Army.

On re-examination March 13 the distortion of the ala seemed less pronounced. The cyst was aspirated again with about the same result as previously, and about 2 cc of lipiodol were injected into it. A second x-ray film outlined the cyst. Some opaque material had extravasated into the soft tissues, probably externally between the cartilage and the skin. The lateral film showed the opaque medium to be primarily anterior. The extent of the cyst could not be seen in the lateral film.

After packing the left inferior nasal meatus with 2% pantocaine with adrenalin, and injecting 2% procaine, to which adrenalin and wydase were added, the left lip and cheek were retracted upwards and an incision was made through the left gingivo-labial fold down to the bone. The periosteum was elevated to the nasal vestibule. The cyst was visualized and when touched ruptured with release of some yellowish fluid with a few rests of lipiodol. It was found to extend approximately to the posterior third of the inferior turbinate, where thickened tissue connected it to the bony wall. It was impossible to separate the medial and superior walls of the growth from the covering mucosa, so the latter had to be removed with it. The inferior meatus was packed with oxycell gauze, and vaseline gauze. The incision in the gingivo-labial fold was closed with interrupted plain catgut sutures and was painted with merchresine and tincture of benzoine. The vaseline gauze packing was removed after two days, and the patient was discharged three days later. After six months, the distortion of the ala had somewhat receded, and the mucosa on the floor of the nose and the left inferior turbinate had a nearly normal appearance.

The specimen consisted of multiple irregular fragments of tan tissue several of which had a polypoid structure and were covered with mucous membrane. Sections revealed multiple polypoid structures lined with stratified columnar epithelium. The stroma was edematous and contained numerous relatively thick-walled vascular channels. Fragments of bone were present. Collections of mucous secreting glands were present particularly near the periphery. Lymphocytes, plasma cells rarely eosinophils were present predominantly in the submucosal layers.

It is interesting to speculate on the origin of these cysts. Terracol and Gesp share the belief of other authors, quoted by them, that they are congenital. The only question to be answered is from which

structure they develop. It is unlikely that they originate from Jacobson's canal, as believed by some, as these cysts are independent of the septum. The Stenson or incisive canal does give origin to serous mucous cysts, however such cysts are found in the midline and are situated lower. Probably the cysts of the nasal vestibule are remnants of an anterior elongation of the naso-lacrimal duct, which is found under the anterior tip of the inferior turbinate in the embryo. This theory seems to find confirmation in the research of F. Lemaitre, Tuffers and Peters, Bolk and Bochdalek.[2]

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Abstracts of Current Articles

EAR

Nerve Deafness of Sudden Onset and of Unknown Etiology.

Horiguchi, N.: The Jour. of the Otorhinolaryng. Soc. of Japan 56:520-527, 1953.

Fifty cases (27 males and 23 females) of deafness occurring suddenly without any known cause were studied by Horiguchi.

1. The largest number of patients were in their twenties.

2. In most cases deafness occurred in sleep, and after physical or mental overwork.

3. Unilateral involvement was three times as frequent as bilateral deafness.

4. All cases were accompanied by tinnitus, and 38 of them by vertigo.

5. Those with vertigo showed a greater degree of impairment of hearing than those without it.

6. Vestibular hypofunction was found in cases with marked hearing loss.

7. Capillary microscopy of the nail bed of fingers revealed the presence of bleeding diathesis in most cases.

8. Capillary resistance against the negative pressure (Borbely's test) was markedly low in most cases.

9. In many cases tinnitus was affected by galvanic current sent through the head.

From these observations the author concluded that the bleeding of the inner ear vessels may be a possible cause of sudden deafness.

HARA.

The Relation Between the Hearing and the Degree of Middle Ear Pneumatization.

Haraguchi, S.: The Jour. of the Otorhinolaryng. Soc. of Japan 56:595.

The author classified roentgenologically the middle ear pneumatization with regard to its degree of development into three groups: a) over-developed, b) well-developed and c) undeveloped. Audiometric examination was made on 18 cases with over-developed pneu-

matization, 22 cases with bilaterally undeveloped and 16 cases with unilaterally undeveloped air cell system, selected from 206 healthy youths. No remarkable difference was found in the threshold for air-conducted sound between the groups with over-developed and undeveloped pneumatization. The threshold for bone conduction sound in the latter was about 5 db lower than that in the former, using frequency between 256 to 2048 cps. In the well-developed cases the hearing gain for bone conducted sound with the external canal closed was 10 to 20 db for low frequencies. In the undeveloped individuals it was only about 5 db. From these results the author discussed the part played by the air cell system in hearing.

HARA.

Efficiency of Ear Plugs as a Protective Measure Against Noise in Retarding the Development of Occupational Deafness.

Doi, K.: Jour. of the Otorhinolaryng. Soc. of Japan 56:687 (Sept.) 1953.

The group of workers who wore cotton-plugs as an ear protector when they were exposed to the noise at a shipyard incurred less hearing loss than workers who never wore the ear protector.

It was, however, experimentally found that the efficiency of cotton plugs as protectors was very small, while ear plugs made of a plastic material were much more effective against noise.

Since these ear protectors are ineffective against noises louder than 50 db, and there is the possibility of injury of the internal ear caused by bone conduction of the sound, no complete protection against occupational deafness has yet been devised.

HARA.

The Roles of Sensation Level and of Sound Pressure In Producing Reversible Auditory Fatigue.

Harris, J. Donald: Laryngoscope 64:2:89-97 (Feb.) 1954.

The determination of unusual susceptibility to auditory fatigue is an important step in any noise control program. Several workers including Smith, Wilson and Peyser suggested stimulation with pure tones and determination of the threshold shift. This author proposed to investigate the relative effectiveness of loudness and intensity in producing auditory fatiue. It was felt that these data would help standardize a fatigue test which would aid in predicting irreversible trauma.

Thresholds of 66 subjects were obtained at 2048 and 4096 cps. A fatiguing stimulus at 2048 cps was presented to each subject for five minutes via earphones. Sound pressure level was maintained at 97 db (80 db above normal on American audiometers). Hearing for 4096 cps was tested by a pulsing tone turned off and on at three-fourths sound intervals.

From the data it was concluded that the fatigue effect could not be predicted from the sound pressure level. At intensities above 60 db, the sensation level must be considered the more important factor in predicting susceptibility to fatigue.

Some discrepancy existed between these data and that of Wilson. More rapid recovery was found than reported by Wilson. The author suggests that a better criterion of fatigue be either the time in seconds to return to within 5 db of the patient's own threshold or the residual hearing loss after one minute.

It is emphasized that a pulsing tone rather than a steady tone be used in determining threshold during recovery in order to minimize the masking effects of the high tone tinnitus which often results from the stimulating tone.

SENTURIA.

The Electrolytes of the Labyrinthine Fluids.

Smith, Catherine A., Lowry, Oliver H. and Wu, Mei-Ling: Laryngoscope 64:3: 141-153 (Mar.) 1954.

Little is known about the normal composition of endolymph and perilymph. It appeared from available data that labyrinthine fluids differ but slightly from spinal fluid and from each other, but the evidence has been conflicting as to the permeability of the various membranous barriers.

To supplement this incomplete information regarding the composition and movement of labyrinthine fluids, the endolymph, perilymph, spinal fluid and plasma of the guinea pigs have been analyzed for sodium, potassium, chlorine and protein by the authors. Because of the limited amounts of fluid available, special micropipette tubes and microchemical techniques had to be developed or adapted specifically for the purpose. A total of 350 analyses were performed on serum, spinal fluid and labyrinthine fluids from 53 guinea pigs. The data presented show that endolymph in the guinea pig is unique among known extracellular fluids and resembles intracellular fluids in regard to sodium and potassium content. Thus sodium and potassium concentration are almost reversed in utricular endolymph

and perilymph. The endolymph potassium concentration is 30 times that of the perilymph and the spinal fluid, whereas the sodium concentration is 10 times higher in perilymph than in endolymph. No difference was found in the concentration of sodium, potassium and chlorine between perilymph and spinal fluid.

Although the analyses of cochlear endolymph are fewer in number and less successful than those of the utricular endolymph the findings are essentially the same.

It would appear that endolymph contains no more protein than spinal fluid but that perilymph may contain twice as much protein as either of the other fluids.

SENTURIA.

NOSE

Experimental Pathological Study of Nasal Mucous Membrane.

Hara, K.: The Jour. of the Otorhinolaryng. Soc. of Japan 56:463-468, 1953.

By injecting such pigments as ink of squid and drawing ink and metallic poisons, e.g. bismuth, silver, and mercury into the peritoneal cavity of adult mice possibility of these pigments and metallic granules being eliminated into the nasal cavity was histologically investigated.

Pathological changes of nasal mucous membrane in the presence of systemic infection was investigated histologically by injecting such objects as diphtheria toxin and staphylococcic toxoid, and animal poisons like hepatoxin besides metallic poisons into the peritoneal cavity of animals. The results were as follows:

1. On the nasal mucous membrane acute inflammatory or regressive changes were observed, though the degree of the changes differed from case to case, and on the respiratory mucous membrane marked inflammatory changes of catarrhal or suppurative type were present. On the olfactory mucous membrane a regressive picture of degeneration, collapse and destruction was conspicuous. All these changes were most marked in the nasal cavity and in a much less degree in the accessory sinuses and Jacobson's organ.

2. Pathological changes mentioned above were marked in cases of metallic poisons, especially mercury and bismuth. They were generally slight in cases of bacterial toxins, except diphtheria toxin which induced intensive changes. Inflammatory changes were hardly to be found when hepatoxin, an animal poison, was applied.

HARA.

THROAT

The Dangers of Tonsillectomy In Pulmonary Tuberculosis.

Hanel, F. and Duve, W.: Zeitschift Für Laryngologie, Rhinologie, Otologie 32:154-158 (Mar.) 1953.

The authors call attention to the danger in young adults and adolescents of lighting up a latent pulmonary tuberculous focus by performing a tonsillectomy. They base their conclusion on a study of fifty-four cases of such re-activated pulmonary tuberculosis in young adults and adolescents, encountered by them in a German tuberculous sanitarium. It is their opinion that removal of part of the lymphatic system, such as the tonsils, in some way weakens the general defenses of the body against the tuberculous infection.

HARKINS.

LARYNX

Neurinoma of the Larynx.

Offenhammer, Kurt: Zeitschrift Für Laryngologie, Rhinologie, Otologie 33:81-89 (Feb.) 1954.

A case is reported of a neurinoma of the larynx occurring in a fifty-six year old man. When first examined there was a history of hoarseness of six months' duration. At that time there was a small tumor described as the size of a lentil, on the right vocal cord at the anterior commissure. This tumor showed histologically the typical picture of a papilloma. However, two weeks later the patient presented himself again with more tumor tissue at the site of removal of the first one—described as not much larger than the head of a pin. When removed this showed histologically the picture of a very cellular fibroma approaching the structure of granuloma. When seen two weeks later the larynx appeared to be perfectly clear.

Now the interesting feature of this case is the rapidity with which the neurinoma appeared. After leaving the clinic with an apparently normal larynx, the patient returned in only two months, with an enormous tumor in the larynx, making immediate tracheotomy necessary. The tumor was removed through a classical thyrotomy. The neoplasm was described as approximately the size of a hen's egg, measuring 5 cm in its longest diameter. It was a smooth, slightly lobulated mass, attached to the anterior portion of the right vocal cord, almost completely filling the supraglottic part of the larynx. Histologically it showed a structure of spindle cells, lying

in more or less parallel bands, in part, interwoven and in part, arranged in whorls and eddies. The nuclei were oval with a tendency to flattening of the poles. The blood vessels were in immediate apposition to the tumor cells; some vessels showed thrombosis. There were occasional giant cells and a few areas of necrosis and hyalinization. In some areas edema was present.

A photomicrograph is included in the report. The author has included, also, a tabular review of thirty-five cases of neurinoma of the larynx collected from the literature.

HARKINS.

Acromegaly of the Larynx.

Matzker, Joseph: *Zeitschift Für Laryngologie, Rhinologie, Otologie* 33:77-80 (Feb.) 1954.

A case is presented of a sixty-eight year old man with acromegaly. A detailed description of the larynx is given. The arytenoid eminences are greatly thickened. Consequently the vocal cords are almost completely covered by these soft tissue swellings, and there is a certain degree of inspiratory stridor. On inspiration the enlarged aryepiglottic folds and arytenoid eminences close in like a valve. Both vocal cords are pale and unusually broad (i.e. thick). The subglottic area shows no abnormality. The swollen arytenoid eminences and aryepiglottic folds apparently caused considerable dsyphagia. The voice is described as deeper than normal (lower pitched), but weak, husky and "cracking." Speaking is an effort for the patient and caused obvious fatigue, due, in part, to the enormous swelling of the tongue.

The question of tracheotomy was considered, but this operation was not done, since the patient apparently was breathing without much difficulty, when at rest.

HARKINS.

Diagnostic X-Ray Technic, Using Concentration of Rays and Hard Rays, As Applied to the Larynx.

Reinike, A.: *Zeitschift Für Laryngologie, Rhinologie, Otologie* 33:176-181 (Mar.) 1954.

The author describes his technique of taking x-ray views of the larynx, in order to bring out the soft tissue shadows and profiles of the laryngeal structures. Several illustrations are given which

show these structures very clearly, in posterior-anterior views. He utilizes a diagnostic roentgen tube with a sharp focus, which makes possible a concentration of rays, and, at the same time, the use of so-called hard rays. One hundred twenty kilovolts are used (for 0.06 to 0.10 sec.), and a much better soft tissue shadow is attained, since the bone shadows (vertebrae) suffer a marked loss of contrast, whereas the soft tissues are not much influenced by the hard rays. By this technique, in contrast to tomography, only one film is necessary in order to obtain ventricular hands, vocal cords, sinus pyriformis, sinus morgagni, and subglottic tissues. Actually he takes two views: one in inspiration and one in phonation. Thereby one obtains a comprehensive picture of the form and motility of the vocal cords and the width of the airway. Some practice is necessary to learn to pick out these soft tissue profiles in these views. Comparison of the inspiratory phase view and the phonatory phase view is helpful, since during phonation the larynx moves upward. The vertebral shadows remain fixed and appear as a somewhat blurred background. Views are illustrated of vocal paralysis, of carcinoma of one ventricular band and of one vocal cord, a subglottic carcinoma and a view of a fibroma.

HARKINS.

MISCELLANEOUS

Eosinophilic Granuloma.

Cruz, S. F.: Rev. Cubana Oto-rino-laringol. 2:8:195, 1953.

This condition, like the Hand-Schüller-Christian syndrome, Niemann-Pick's disease, Gaucher's disease, and possibly amaurotic familial idiocy (Tay-Sachs disease), is due to disturbances of lipid metabolism in the form of lipiodosis or xanthomatosis.

According to some authorities, the granuloma is restricted to the skeletal system, and does not affect the internal organs nor the general health of the patient. In the early stages the granuloma is a nodular process resembling an inflammatory massive infiltration by eosinophils and proliferation of phagocytes. Later the eosinophils disappear, and are replaced by foam cells and fibroblasts. In subsequent stages an extensive metaplastic, fibrous tissue develops. These lesions tend to form isolated foci.

The disease is observed in older children and young adults, but may also occur in the case of infants and older adults. The lesions

appear as rarefied or cystic areas affecting one or more bony structures, especially the cranial bones, ribs, and vertebrae. Pain may attack suddenly, but usually the onset is insidious and asymptomatic, and the diagnosis can be established only by roentgenography, which reveals the granuloma, and by biopsy and the clinical course. In rare instances fever occurs. The duration of the condition varies from a few months to two or three years. Recovery may be spontaneous.

The blood picture sometimes reveals leucocytosis, and frequently a moderate eosinophilia; the blood cholesterol content may be increased.

The isolated foci may be removed surgically but if there are multiple lesions, radiotherapy is the most effective method.

A case is cited of infectious granuloma of the upper gingival mucosa, in a child fifteen months of age. The lesions were numerous, bleeding and emitting a purulent fluid. The upper teeth were loose. The right auditory passage was filled with numerous polyps, which exuded profuse pus. The condition had been present for two months, and had not responded to antibiotics.

Laboratory tests of the pus revealed Staphylococcus aureus, diphtheroid bacilli, Klebsiella, Streptococcus viridans, Staphylococcus haemolyticus, Escherichia coli, and Pseudomonas, but no Monillia. The feces contained a few Trichocephalus ova (Trichuris).

Biopsy of the stratified epithelium in the vicinity of the lesions and of the exudate, revealed histiocytes, a proliferative monocytic and histiocytic lesion with a large number of eosinophils, and slight sclerosis. The condition was diagnosed as the initial stage of eosinophil granuloma. Roentgenography revealed vague osteoporosis of the femur, which disappeared later.

Treatment consisted of surgical curettage of the mucosal lesions in the palatal arch and in the gingivae, and also of the granuloma in the ear. Specific antibiotics were given, and gentian violet was supplied locally.

Definite improvement followed the treatment. The granuloma was replaced by fibrous tissue. The patient was lost sight of before recovery was complete.

HIGBEE.

Camphor Poisoning Following Ingestion of Nose Drops.

Seife, Marvin and Leon, Jerome L.: *J. A. M. A.* 155:1059 (July 17) 1954.

The authors report a case of severe champhor poisoning in a 48-year-old nurse's aid who had ingested some 7.5 cc of a proprietary remedy (Vick's Va-Tro-Nol oily nose drops) which she had swallowed in the course of nasal instillation. Three hours later there occurred malaise and dizziness, after which she fell to the floor, foaming at the mouth, and had an epileptiform convulsion lasting one minute. No radial pulse was obtainable at first, but after five minutes it returned (100 beats per minute) and the blood pressure registered 120/70. The rectal temperature was 98.8. There was no incontinence.

She was able to return to work a few days later, apparently none the worse for her experience.

According to the authors fatal camphor poisoning is uncommon, but has occurred.

Ten Years' Experience in the Use of Tantalum in Frontal Sinus Surgery.

Goodale, Robert L.: *The Laryngoscope* 64:2:65-72 (Feb.) 1954.

The author presents his experience during the past ten years with the use of tantalum foil sutured to the orbital periosteum as a method of maintaining drainage from selected cases in which the Lynch technique was used in frontal sinus surgery.

A total of 20 patients were operated upon prior to 1945 and were available for evaluation. Four cases are described which are illustrative of the excellent results. The foil was tolerated without discomfort and the passage between the orbital periosteum and the midline remained clear.

Some of the defects and errors in this technique are presented: 1. Improper positioning of the foil may prevent proper union of the skin edges. 2. The tatalum may be mistakingly removed as a foreign body. 3. Injudicious probing may displace the foil so that it does not remain at the proper level in the nose.

The author does not regard this technique as a routine procedure to supplant the obliterative operation. He suggests rather that it should be considered in difficult cases when reinfection is likely and where the problem is one of maintaining adequate frontal sinus drainage.

SENTURIA.

Notices

SIXTH INTERNATIONAL CONGRESS OF OTOLARYNGOLOGY

May 5-10, 1957 are the dates finally selected for the Sixth International Congress of Otolaryngology. The sessions will be held in Washington, D. C. with headquarters at the Statler Hotel. Plans for the scientific programs and for the accomodation and entertainment of the visiting members will be announced.

Paul H. Holinger, M.D.
Secretary General
700 N. Michigan Ave.
Chicago 11, Illinois

Arthur W. Proetz, M.D.
President

AMERICAN BOARD OF OTOLARYNGOLOGY

The American Board of Otolaryngology will conduct the following examinations:

September 13-17, 1954, in New York City, at the Waldorf Astoria Hotel.

March 6-10, 1955, in Richmond, Virginia, at the Hotel Marshall.

UNIVERSITY OF ILLINOIS

The next Bronchoesophagology Course to be given by the University of Illinois College of Medicine is scheduled for the period November 8 through 20, 1954. The course is under the direction of Dr. Paul H. Holinger.

Interested registrants will please write directly to the Department of Otolaryngology, University of Illinois College of Medicine, 1853 West Polk Street, Chicago 12, Illinois.

AMERICAN LARYNGOLOGICAL ASSOCIATION

CASSELBERRY PRIZE

A sufficient sum having accrued from the Casselberry Fund for encouraging advancement in the art and science of Laryngology and Rhinology, this sum is now available, in part or as a whole, for a prize award. Theses must be in the hands of the Secretary, Dr. Harry P. Schenck, 326 South 19th Street, Philadelphia, Pa., before March 1, 1955.

Copies of the Transactions of the American Laryngological Association are available for general distribution at $8.00 a copy. Please send request with check to:

Dr. Bernard J. McMahon,
Editor Transactions
8230 Forsyth Blvd.
Clayton 24, Mo.

UNIVERSITY OF PENNSYLVANIA

Announcement is made of the personal fundamental course in Bronchology, Esophagology, Gastroscopy and Laryngeal Surgery at the Graduate School of Medicine, University of Pennsylvania. The course begins September eighth and continues through September nineteenth.

Courses are scheduled usually in January, June and September avoiding conflict with the meeting dates of the National Medical Societies.

Application may be made to Dr. Aims C. McGuinness, Dean, or to Dr. Gabriel Tucker, Chairman of the Department of Bronchology, Esophagology, and Laryngeal Surgery.

TULANE UNIVERSITY OF LOUISIANA
SCHOOL OF MEDICINE

The three year residency in otolaryngology offered at Charity Hospital of Louisiana at New Orleans on the Tulane University of Louisiana School of Medicine service is designed to qualify the holder

for the examinations of the American Board of Otolaryngology and the practice of all phases of otolaryngology and endoscopy.

Candidates must be graduates of a class A medical school and must have completed a minimum of one year of general internship. An additional year of residency in internal medicine or general surgery is desirable but not essential.

All work is under the direct supervision of members of the Tulane Department of Otolaryngology, who are also members of the Charity Hospital Otolaryngological Staff; they are available at all times for instruction and guidance. Basic sciences are offered throughout each year of the residency during the academic year. The resident also participates in the program of the Speech and Hearing Center at the Tulane University School of Medicine.

The hospital year extends from July 1 of one year to June 30 of the following year.

Applications should be addressed to the Chairman of the Department of Otolaryngology, Tulane University of Louisiana School of Medicine, 1430 Tulane Ave., New Orleans 12, Louisiana.

FOURTEENTH JAPAN MEDICAL CONGRESS

The Fourteenth Japan Medical Congress will be held in Kyoto, April 1-5, 1955. Particulars may be had of the Secretary General, Mitsuharu Goto, University Hospital Kyoto University, Kyoto, Japan.

PORTUGESE OTORHINOLARYNGOLOGICAL SOCIETY

On March 20 the Sociedade Portuguesa de Otorrinolaringologia e de Bronco-esofogologia was founded, and held its first meeting in Lisbon under the presidency of Dr. Alberto Luís de Mendonça. The Secretary is Dr. António da Costa Quinta, Avenida de Liberdade 65, 1° Lisbon.

PAN-AMERICAN SURGICAL ASSOCIATION

Doctors are cordially invited to attend the Sixth Congress of the Pan-Pacific Surgical Association to be held in Honolulu, October 7-8, 1954.

For further information, please write to F. J. Pinkerton, M.D., Director General, Pan-Pacific Surgical Association, Suite 7, Young Building, Honolulu, Hawaii.

IV INTERNATIONAL CONGRESS

There are a few copies of the Proceedings of the 4th International Congress of Otolaryngology still available for purchase.

The publication contains all of the numerous papers, and is well produced. Copies may be had, at Five Guineas, from

The Secretary
British Medical Journal
B. M. A. House
Tavistock Square
London, W. C. 1.

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OFFICERS

OF THE

NATIONAL OTOLARYNGOLOGICAL SOCIETIES

American Academy of Ophthalmology and Otolaryngology

President: Dr. Derrick Vail, 700 N. Michigan Blvd., Chicago 11, Ill.
Executive Secretary: Dr. William L. Benedict, Mayo Clinic, Rochester, Minn.

American Board of Otolaryngology

President: Dr. Frederick T. Hill, Professional Bldg., Waterville, Maine.
Secretary: Dr. Dean M. Lierle, University Hospital, Iowa City, Iowa.
Next examination: Richmond, Va., March 6-10, 1955.

American Broncho-Esophagological Association

President: Dr. Clyde A. Heatly, 11 N. Goodman St., Rochester, N. Y.
Secretary: Dr. F. Johnson Putney, 1719 Rittenhouse Sq., Philadelphia 3, Pa.
Meeting: Hollywood, Florida, March 15 and 16, 1955.

American Laryngological Association

President: Dr. Henry B. Orton, 224 Delavan Ave., Newark, N. J.
Secretary: Dr. Harry P. Schenck, 326 South 19th St., Philadelphia, Pa.
Meeting: Hollywood, Fla., March 13-14, 1955.

American Laryngological, Rhinological and Otological Society, Inc.

President: Dr. Kenneth M. Day, 121 University Place, Pittsburgh, Pa.
Secretary: Dr. C. Stewart Nash, 708 Medical Arts Bldg., Rochester, N. Y.
Meeting: Hollywood, Fla., March 15, 16, 17, 1955.

American Medical Association, Section on Laryngology, Otology and Rhinology

Chairman: Dr. Francis W. Davison, Danville, Pa.
Secretary: Dr. Hugh A. Kuhn, Hammond, Ind.

American Otological Society

President: Dr. D. E. Staunton Wishart, 170 St. George St., Toronto 5, Can.
Secretary-Treasurer: Dr. John R. Lindsay, 950 East 59th St., Chicago 37, Ill.
Meeting: Hollywood, Fla., March 17-18, 1954.

The American Society of Ophthalmologic and Otolaryngologic Allergy

President: Albert D. Ruedemann, M.D., Detroit, Mich.
Secretary-Treasurer: Michael H. Barone, M.D., Buffalo, N. Y.
Meeting: New York City, September, 1954.

VI International Congress of Otolaryngology

President: Arthur W. Proetz, M.D., St. Louis, U. S. A.
Secretary-General: Paul H. Holinger, M.D., 700 North Michigan Ave., Chicago 11, Ill., U. S. A.
Meeting: Washington, D. C., May 5-10, 1957.

International Bronchoesophagological Society

President: Dr. Andre Soulas, Paris, France.
Secretary: Dr. Chevalier L. Jackson, 1901 Walnut St., Philadelphia 3, Pa., U.S.A.
Meeting: Third International Congress of Bronchoesophagology, September or October, 1954, Lisbon, Portugal.

Pacific Coast Oto-Ophthalmological Society

President: Leland G. Hunnicutt, M.D., 98 N. Madison Ave., Pasadena 1, Calif.
Secretary-Treasurer: John F. Tolan, M.D., 3419 47th Ave., N.E., Seattle 5, Wash.
Meeting: Honolulu, 1954.

Pan-American Association of Oto-Rhino-Laryngology and Broncho-Esophagology

President: Dr. Justo M. Alonso, Montevideo.
Secretary: Dr. Chevalier L. Jackson, 1901 Walnut St., Philadelphia 3, Pa., U.S.A.

Canadian Otolaryngological Society

President: Dr. Robert Black, 401 Medical Arts Bldg., Winnipeg, Manitoba.
Secretary: Dr. W. Ross Wright, 361 Regent St., Fredericton, N. B.
Meeting: Harrison Hot Springs Spa, Harrison Hot Springs, B. C., June 13th to 15th, 1954.